TECHNOLOGY DEPARTMENT
First Copy

Iron and Steel Engineer

Established 1907 as Proceedings of A. I. & S. E. E.

J. F. KELLY, Editor

First Copy
TECHNOLOGY DEPARTMENT

CONTENTS

Vol. V. June, 1928 No. VI.

Official Program for Twenty-fourth Annual Convention and Iron and Steel Exposition III

Our Convention and Exposition—By A. J. Standing V

The Executive—By Martin J. Conway VI

Electrical Progress in Steel Plants—By A. L. Reichert VII

Conservative Economy in Power Service—By D. M. Petty VII

The Contribution of Safety to the Iron and Steel Industry—By John A. Oartel IX

Electrification as a Means of Reducing Costs—By G. E. Stoltz X

The Future of Safety—By Frank H. Rowe XI

The Evolution of the Application of Electricity to the Manufacture of Steel—By Geo. J. Walz XIII

List of Manufacturers Exhibiting at Iron and Steel Exposition XV

Yearly Review, Electricical Developments Iron and Steel Industry—W. H. Burr, Chairman 211

Selection of Motors for Main Drives of Merchant, Bar and Rod Mills—By C. B. Houston 218

Factors Governing the Purchase of Coal—By Morgan B. Smith 230

Present Practices in Connection with Motor Driven Rollers—By J. C. Dobelbower 235

Boiler Pressure Above 500 Pounds—By J. B Crane 237

Steel Mill High Tension Practices—By F. O. Schnure 240

Anti-Friction Bearings for Auxiliaries in the Iron and Steel Industry—By E. S. Jefferies 242

Anti-Friction Bearings for Electric Motors—By J. S. Murray 243

The Selection of Main Drive Motors for Strip and Skelp Mills—By A. F. Kenyon 248

Rules and Regulations Pertaining to Operation of a Steel Plant High Tension System—By R. M. Hussey 255

The Insulation of Open-Hearth Furnace Regenerators—By L. B. McMillan 257

Recording and Controlling Instruments in the Iron and Steel Industry—By C. C. Eagle and R. M. Walker 263

Discussion of the Elements Entering Into the Cost of Producing Power—By W. B. Skinkle 278

Report of Committee on Electric Heat—By Geo. H. Schaeffer, Chairman 291

High Tension Practice in Modern Plants—By Eugene Vinet 303

Final Outline Dimensions for Association of Iron & Steel Electrical Engineers Standardized Mill Type Motor—By A. C. Cummins, Chairman Standardization Committee 305

Anti-Friction Bearings for Roll Necks—By J. H. Van Campen 308

Junior Membership of A. I. & S. E. E. 311

Floor Plan, Iron & Steel Exposition 314

(List of Advertisers XVI.)

Published Monthly by

Association of Iron and Steel Electrical Engineers

BOARD OF DIRECTORS—1928

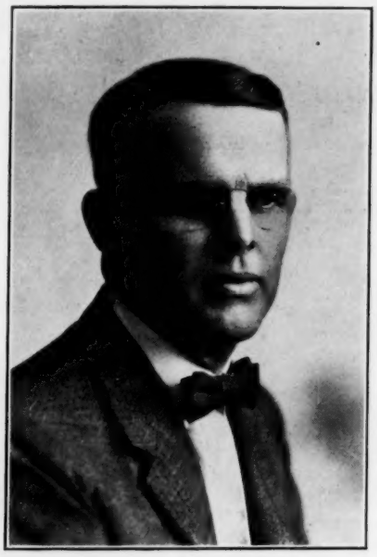
A. J. STANDING, President, Bethlehem Steel Company, Bethlehem, Pa.

C. S. PROUDFOOT, 1st V. Pres.—United States Ferro Alloys Corp., Niagara Falls, N. Y.
F. W. CRAMER, 2nd Vice Pres.—Bethlehem Steel Co., Johnstown, Pa.
S. S. WALES, Past President—Carnegie Steel Co., Pittsburgh, Pa.
GEORGE H. SCHAEFFER, Past Pres.—Carpenter Steel Co., Reading, Pa.
JAMES FARRINGTON, Treasurer—Wheeling Steel Corp., Steubenville, O.
A. G. PLACE, Secy.—Youngstown Sheet & Tube Co., Youngstown, O.
R. S. SHOEMAKER, Director at Large, American Rolling Mills, Middletown, O.
W. J. HARPER, Director—Donner Steel Co., Buffalo, N. Y.
JOHN A. OARTEL, Director—Carnegie Steel Co., Pittsburgh, Pa.
ELBERT LEWIS, Director—Illinois Steel Co., South Chicago, Ill.
W. W. GARRET, Director—Tennessee Coal, Iron & Railroad Co., Fairfield, Ala.
A. L. REICHERT, Director—Bourne Fuller Co., Cleveland, Ohio.
E. FRIEDLAENDER, Honorary Director—Pittsburgh, Pa.

JOHN F. KELLY, Managing Director—Empire Building, Pittsburgh, Pa.

Entered as second-class matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879.
Subscription Price $5.00 per Year. Single Copy 50c.

J. S. MURRAY, Chief Elec. Engr., Follansbee Bros. Co., Follansbee, W. Va., Author.



W. H. BURR, Elec. Supt., Lukens Steel Co., Coatesville, Penna., Author.

GEO. H. SCHAEFFER, Elec. Engr., Carpenter Steel Company, Reading, Penna., Author.

J. C. DOBELBOWER, Engr., Crocker Wheeler Elec. Mfg. Co., Ampere, N. J., Author.

L. B. McMILLAN, Engr., Johns-Manville Corp., New York, N. Y., Author.

A. F. KENYON, Engr., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Penna., Author.

W. B. SKINKLE, Engr., Pittsburgh District Power Committee, Subsidiary Companies of U. S. Steel Corp., Author.

C. B. HUSTON, Engr., General Electric Company, Schenectady, N. Y., Author.

J. H. VAN CAMPEN, Chief Engr., E. W. Bliss Company, Salem, Ohio, Author.

OFFICIAL PROGRAM

Twenty-fourth Annual Convention
and
Iron and Steel Exposition

All technical sessions will be held at the Stevens Hotel

IRON & STEEL EXPOSITION
STEVENS HOTEL, CHICAGO, ILLINOIS
JUNE 25th TO 28th, 1928
9 A. M. to 5 P. M. Each Day

MONDAY, JUNE 25th

9:00 A. M., Registration

9:30 A. M., Business Session—A. J. Standing, Chairman
10:00 A. M.—"Electrical Heating in the Iron and Steel Industry," by A. I. & S. E. E. Electric Heat Committee, G. H. Schaeffer, Chairman.

11:00 A. M.—"Electrical Developments in the Iron and Steel Industry," by A. I. & S. E. E. Electrical Development Committee, W. H. Burr, Chairman.

11:30 A. M.—Report of Electric Welding Committee of the A. I. & S. E. E., A. G. Place, Chairman.

12:00 Noon—Report of Standardization Committee of the A. I. & S. E. E., A. C. Cummins, Chairman.

12:30 P. M.—Informal Luncheon under the auspices of the Safety Engineering Division of the A. I. & S. E. E.

1:30 P. M.—Address by L. H. Burnett, Vice President of the Carnegie Steel Co.

2:00 P. M.—Technical Session, C. L. Baker, Chairman—"Methods and Systems used in High Tension Practices in Modern Plants," by Eugene Vinet, Assistant to Vice President, Middle West Utilities Co., Chicago, Ill. "Steel Mill High Tension Practices," by F. O. Schnure, Electrical Superintendent, Bethlehem Steel Company, Sparrows Point, Md. "Rules and Regulations Pertaining to the Operation of Steel Plants High Tension System," by R. M. Hussey, Electrical Superintendent, Jones & Laughlin Steel Corp., Woodlawn, Penna.

4:00 P. M.—Official Opening of the Iron and Steel Exposition by the Executive Officers of the A. I. & S. E. E.

7:00 P. M.—Informal Reception of the Maintenance Department Employees of the Iron and Steel Plants in and around Chicago at the Iron and Steel Exposition.

9:00 P. M.—Informal Reception in the Ball Room of the Stevens Hotel for the members and guests of the A. I. & S. E. E., C. J. Smith, Chairman.

TUESDAY, JUNE 26th

10:00 A. M.—Technical Session, W. S. Hall, Chairman—"Present Practices in Connection with Motor Driven Rollers," by J. C. Dobelbower, Engineer, Crocker Wheeler Electric Mfg. Co., Ampere, N. J. "The Selection of Motors for Main Drives of Strip and Skelp Mills," by A. F. Kenyon, Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Penna. "The Selection of Motors for Main Drives of Merchant, Bar and Rod Mills," by C. B. Huston, Engineer, General Electric Company, Schenectady, New York.

12:30 P. M.—Informal Luncheon, Special feature—"Demonstration: Making Sound Visible and Light Audible," by J. B. Taylor, Engineer, General Electric Company, Schenectady, N. Y.

WEDNESDAY, JUNE 27th

10:00 A. M.—Technical Session, J. C. McElhinney, Chairman—"Insulation of Open Hearth Furnace Regenerators," by L. B. McMillan, Johns-Manville Corp., New York, N. Y. "Boiler Pressures Above 500 Pounds," by J. B. Crane, Ladd Water Tube Boiler Division, Combustion Engineering Corp., New York, N. Y.

12:30 P. M.—Informal Luncheon, Special feature—"Demonstration of the Wensley Televox or Automatic Man," by J. L. McCoy, Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Penna.

2:00 P. M.—"Factors Governing the Purchase of Coal," by Morgan B. Smith, Engineer of Purchases, General Motors Corp., Detroit, Mich. "Instruments in the Iron and Steel Industry," by C. C. Eagles and R. M. Walker, Engineers, The Bristol Company, New Britain, Conn.

THURSDAY, JUNE 28th

9:30 A. M.—Technical Session, Barton R. Shover, Chairman—"Anti Friction Bearings for Roll Necks," by J. H. VanCampen, Chief Engineer, The E. W. Bliss Company, Salem, Ohio. "Anti Friction Bearings for Motors," by J. S. Murray, Electrical Superintendent, Follansbee Bros. Co., Follansbee, W. Va. "Anti Friction Bearings for Auxiliaries," by E. S. Jefferies, Electrical Engineer, Steel Company of Canada, Ltd., Hamilton, Ontario, Canada.

2:00 P. M.—Technical Session, A. J. Standing, Chairman—"Discussion of the Elements Entering into the Cost of Producing Power," by W. B. Skinkle, Engineer, Pittsburgh District Power Committee, Subsidiary Companies of the United States Steel Corporation.

7:00 P. M.—Annual Reception (Formal Dinner Dance) for Members and Guests, Main Ball Room, Stevens Hotel. J. J. Booth, Chairman.

FRIDAY, JUNE 29th

Inspection Trip

C. L. BAKER, Management's Repr., Bethlehem Steel Co., Johnstown, Penna. General Chairman, Safety Engineering Division, A. I. & S. E. E.

J. J. BOOTH, Asst. Elec. Supt., Gary Tube Co., Gary, Ind. ..General Chairman, Formal Reception, Thursday evening, June 28, 1928.

M. J. CONWAY, Fuel Engr., Lukens Steel Company, Coatesville, Penna. ..General Chairman, Combustion Engineering Division, A. I. & S. E. E.

H. E. DAVIS, Elec. Supt., Interstate Iron & Steel Co., Chicago, Ill. General Chairman, Arrangements Committee, Twenty-fourth Annual Convention.

B. R. SHOVER, Consulting Engineer, Pittsburgh, Pa. General Chairman, Special Bearings Committee, A. I. & S. E. E.

JAMES L. MILLS, Elec. Engr., Illinois Steel Company, Chicago, Ill. ..General Chairman, Registration, Twenty-fourth Annual Convention.

A. R. LINTERN, Floor Manager, Iron and Steel Exposition.

G. E. STOLTZ, Mgr., Ind. Engr. Dept., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Penna., Author.

E. S. JEFFERIES, Elec. Engr., Steel Co. of Canada, Hamilton, Ont., Author

Our Convention and Exposition

By A. J. STANDING*

AS we contemplate the 24th Annual Convention of our Association of Iron & Steel Electrical Engineers to be held in Chicago during the week of June 25th, it is fitting that we consider carefully the status of our Convention with respect to our individual work and usefulness.

Unfortunately when the term Convention is mentioned it too often conveys the impression of a gathering ostensibly for the purpose of gaining knowledge from exchange of ideas and information, but in reality for the main purpose of having a good time. There has perhaps been just cause for the creation of this impression but I feel safe in saying that the technical Conventions of today consider carefully the main objective of their meetings.

We are proud to be able to state with authority that among the active membership of our Association there has always existed a very live sense of our obligation to our Employers to derive the maximum benefit from the Conventions of our Association, both from the standpoint of technical sessions

A. J. STANDING,

as well as from a careful study of the exhibition of equipment which is each year an important feature of our annual gatherings.

An interesting experience which happened to the writer during the 1927 Convention in Pittsburgh will serve to illustrate the point. While inspecting the exhibit of a well known electrical manufacturing company I was introduced to the President of the Company. After a few generalities the President very naturally directed the conversation along the lines of their products. Inasmuch as we have had considerable experience with the products of this Company I was able to discuss the changes and developments of their equipment with considerable assurance backed by the actual use of about 1,200 of these motors of various sizes. As we concluded the conversation which involved many questions and answers the President made the following interesting statement: "The representatives of our company urged me to spend a couple of days in our booth at this convention and I admit it has been a revelation to me to meet you electrical men of the Steel Industry and to hear you discuss our products with authority and confidence supported by the intimate contact with such a large quantity of our appratus." The above statement I think is significant because it justifies our exposition, if any justification is necessary, and it also serves as an interesting side light on the interconnection between the manufacturers and users of electrical equipment in the Steel Plants as the result of which we are instrumental in developing better equipment for our operation.

There is a very valuable opportunity presented to each of us to visit this exhibition privately or better with some of our members from another plant and to examine and discuss the merits or demerits, costs, maintenance troubles, and general characteristics of various equipment on display. Such private discussion usually brings out facts which are not generally touched upon in papers or public discussions. It might be well right here to outline a few suggestions which from our experience seem to be essential to the success of our Conventions.

First: The most vital point is that of attendance because without a large representative gathering our efforts would be practically useless.

Second: Here again I am going to insist that attention to our technical program is important to all of us.

Third: A careful study of the papers and whenever possible an enlightening discussion of points developed.

Fourth: A continual inspection of the exhibits in a systematic way that will give greatest satisfaction to us as individuals and to the exhibitors.

Fifth: Support of any Plant inspection or social opportunity that may be offered.

Sixth: I am placing a very vital feature last on my list solely because it is more or less indefinite. This is individual or informal group discussions of problems which are common to all of us.

Just what bearing do the foregoing suggestions have on our 1928 Convention? I hope that my few remarks will help to prepare us so that we may derive the greatest possible benefit from the Convention as a whole. To this end we must give of our time and effort and if we are not slated to take an active part in the various phases of the Convention we can, by our presence and discussion, add to the efforts of others to make clear the vital points touched upon in the papers and perhaps we may be the means of throwing an entirely new light on a familiar problem.

The fellowship engendered among members of this Association should enable any one to secure, through conversation with other members, certain information that may answer a very pressing question that has just come to light in a given Plant

*President Association Iron & Steel Electrical Engineers.

whereas this question may have been satisfactorily solved elsewhere.

A very interesting and instructive feature of all our Conventions has been the opportunity to visit some Industrial Plant where we can see operations that interest us and maybe of great value to us at some time in our own Plant.

In concluding these few remarks I want to take this last opportunity, as President of this Association, to express to the officers and members my conviction that the Association of Iron & Steel Electrical Engineers will continue to progress just so long as we individuals continue to keep our minds on our jobs and strive to further, by our knowledge and practice, the electrical and general engineering developments of the Steel Industry to which our Association owes its very right to exist. Our Association has a solidarity which is unchanged by the passing of Officers largely because there are always capable men ready to step into our places and particularly because with most of us the passing out of office does not mean the discontinuance of our active interest in the affairs of the Association even though we may not feel justified in giving quite so much of our time to its work. The Association of Iron & Steel Electrical Engineers will always look to those who have been its leaders for help and council through the medium of the Board of Advisers, composed of Past Presidents, whose opinion as an advisory body will help to shape the future policies of our Association.

The Executive

By MARTIN J. CONWAY*

IN industrial nomenclature an executive is a man who is responsible for the execution of work performed by others and in the last analysis we hold him responsible for the accomplishment of the tasks within his department. It seems to be the opinion of many, that executive skill is a God-given attribute and that such skill cannot be developed.

There are a few essential executive qualities which are doubtless in the nature of a birthright, without which, one can never hope to aspire to executive success. But between those men who have these few qualities in great measure and those men who do not have them at all, there is a larger number of men who are gifted in a moderate degree and the progress of these men may be seriously impaired because of their belief that executive skill is an intuitive faculty which cannot be explained, rather than good leadership, requiring careful penetrative thinking and absolute self-control.

Mans nature, habits and feelings would of necessity throw him back into the cave days of his ancestors were it not that he has progressed by guiding his emotional pressures into constructive channels. The executive must guide his organization forward by reason, thinking his way along and his actions and desires must agree with the decisions of his mind, rather than to the hills and valleys of his emotional nature. His duty is to receive orders from the administrating officials and apportion them to the employees in his department in such a way that the work progresses smoothly and at a pace which co-ordinates with that of other departments, this calls for an innate interest in and understanding of the men he directs.

It has been said that you cannot throw a crowd of men together and expect to have a successful organization any more than you may place a man, a woman and children within a house and expect to have a happy family.

The successful executive is a maker of men and finds happiness in hastening their self improvement and progress. As a man-maker he believes in his men "by and large" seeking out the strong points in each man and providing incentive for their translation into economic value.

An executive requires a certain amount of personality, a quality which is not easy to describe except as a vigor or virility which seems to spring from the nervous system and is not confined to any particular type of intellectual or physical make-up, but finds outlet in a sturdy determination which does not lessen until the task at hand has been accomplished. This characteristic is undoubtedly one of the basic elements justifying a natural right to be an executive. After all the executive group are the nervous system of the main organization and through them must flow the impulses of action to be transmitted to the men.

Another essential quality necessary in the make-up of an executive is a scientific trend of mind to help him face the problems which yield most readily to analytical approach.

The problems the executive must solve in co-ordinating the work of a group of men, materials and equipment in a way that maximum quantity and quality with minimum waste is obtained is exceedingly complex and requires solution well in advance of the actual achievement. The successful executive solves most of his problems through preventive rather than curative action and this planning for the future calls for a trend of thought which is distinctly scientific and a sense of discrimination between fact and opinion.

To attempt to list all of the traits essential for executive success would be futile, but those which should be possessed in a greater degree only have been mentioned. These traits are: A profound interest in the men directly in contact, power of personality and a well balanced scientific trend of thought.

*Fuel Engr., Lukens Steel Co., Coatesville, Pa.

Electrical Progress in Steel Plants

By A. L. REICHERT*

THE established marked economies in electric operation in the steel plants have resulted in this type of operation being adopted practically 100% in all new mills laid down in recent years. Many old mills which were originally steam driven have been changed over to electric drive. At the present time at least 55% of all rolling mills in this country are electrically driven. This percentage is rapidly increasing as many old mills are being changed over to electric drive every year in addition to new mills being installed.

The first main roll electric drive in the United States was installed twenty-three years ago and at the present time there is in round numbers 2,000,000 H.P. installed for driving main rolls in this country. This is increasing at an average rate of about 13% per year.

In the early days of electric drive a motor was merely used to replace an engine as a means of producing the necessary torque and speed to drive the mill. Within recent years it has developed that electric motors can be designed to have special characteristics which are being taken advantage of, to improve the mill design itself. As an example, direct current motors have been built that have inherent flat speed characteristics necessary for driving successfully the individual stands of the new continuous type wide strip mills. It is very probable that this type of mill could not have come into existence without the availability of the direct current electric motor with its flat speed regulation to driev it. There are also several continuous type merchant mills in operation or being installed, that have individually driven stands. These mills are laid out with only 8′ or 10′ spacing between stands and delivery speeds sometimes exceed 2500 ft. per minute. These mills require adjustable speed drives and the material is light and cannot stand any pulling or buckling. These mills are successfully driven with direct current adjustable speed motors and in some cases these motors are provided with special speed matching equipment, so that the several motors driving the various stands are caused to operate practically in synchronism with each other. The relative speeds of the various stands are adjustable, but when once set the ratio is maintained throughout all values of operating load. This is a result that could be accomplished only with electric drive and has the advantage of providing an extremely flexible mill. In this way the field of the continuous type of mill has been widened to include finishing mills where formerly it was used only on semi-finishing mills.

There has been much progress made during recent years in the steel mill auxiliary field, such for instance as the development of automatic control for screwdowns, the control of soaking pit covers and the ingot buggy from the soaking pit crane, etc. These result in the saving of labor and the reducing of costs.

There has been placed in service during the last year two electrically driven flying shears.

The use of definite time positive acceleration control of steel mill auxiliaries has been extended.

There is also a more extensive application of individual motor driven rollers on continuous runout tables and this is being considered for certain tables that start and stop frequently and even some that are required to reverse.

Some of the steel mill generating plants now compare favorably with the average central station plants and are using generating units up to as large as 30,000 K.W. capacity. The use of these larger units and steam pressures up to 350 pounds also results in greater economy of operation.

The use of electric drive has provided a means of obtaining reliable data on the various phases of steel plant operation. By means of graphic and integrating meters and the oscillograph analyses have been made and from these data the application of electric drive is made scientific. This means that practically any problem pertaining to the driving of rolling mill machinery can be put up to the electrical engineer and a solution worked out. Many intricate problems involving automatic and remote control features, such as mentioned above, have been successfully solved. Mill designers are depending more and more on the work of the electrical engineer for assistance in solving difficult mill problems. The electrical engineer in the steel plant of today has become a real factor in the successful and economical operation of the plant.

*Elec. Engr., Bourne Fuller Co., Cleveland, O.

Conservative Economy in Power Service

By D. M. PETTY*

DUE to the great effort to eliminate power delays that has been extended in the past "Perfection" in the operation of the power supply for a Rolling Mill has come to mean absolute freedom from power interruptions.

This idea of perfection has been so strongly advocated that the cost of obtaining it has frequently been overlooked. It is the purpose of this discussion to outline some of costs that go along with absolute insurance against power interruptions and to suggest that there are conditions under

*Elec. Supt., Bethlehem Steel Co., Lehigh Plant, Bethlehem, Pa.

which the old fashioned "Delay" should more properly be called a "Postponement of Production."

The cost of power is made up of two parts:

1. Capital cost which includes interest on capital, depreciation, and obsolesence on apparatus, taxes, etc.

2. Operating cost, which includes fuel, labor and supplies.

The proper ratio between these two major divisions of costs should always be maintained. One of the several factors which determine the proper ratio is, the importance of continuity of service to the manufacturing plant which depends upon a power station for its operation. If a power interruption means expensive burnouts, or in any way does extensive damage to machinery; or when the product of the plant is 100% sold, interruptions are expensive and the power plant should be designed to eliminate, as far as possible, these power interruptions. On the other hand, if a power interruption does not damage machinery, or a postponement of production for a short time does not represent a loss of profits, inasmuch as the producing capacity of the plant is not 100% sold, then the power plant need not necessarily be built so as to insure against every possible kind of power failure.

The cost of a single unit 5,000 K.W. steam turbine plant, using barometric condensers, steam pressure in the order of 300 pounds 200° superheat, where condensing water is easily available, should not exceed $500,000. A capital charge of 15% is ordinarily used and would represent an annual charge against operation of $75,000 per year, or $6,250 per month.

This plant will have just enough boilers, say two, to carry full load on a single turbine. There will be no great duplication of water or steam auxiliaries nor electrical switchboard apparatus. Interruptions in a plant of this kind will occur, but with proper week-end maintenance they will not be frequent, and with careful operation should never be of very great duration, especially for the first ten years.

To insure this power plant against interruptions, it would be necessary to install at least three boilers, large enough so that two could carry the full load; a second turbine, as well as a considerable amount of duplicate pumps, piping, etc., in addition to electrical switchboard apparatus so that the first cost will be in the order of $750,000 with an annual capital charge of $112,500 or $9,375 per month.

The operating cost of either plant with 15 to 20% load factor, should not exceed .004 per kilowatt hour, based on the assumption that the boilers will have an operating efficiency of 80%, burning pulverized 14,500 b.t.u. bituminous coal at a cost of $3 per ton delivered to the pulverizers and assuming a 15-pound water rate for the turbine.

Operating single turn with a load of approximately 600,000 K.W. Hours per month, the total cost of power would in the case of a single unit plant be:

Capital charge	.0104 per K.W. Hour
Operating cost	.004 per K.W. Hour
Total	.0144 per K.W. Hour

In the case of a duplicate plant, the costs under the same conditions of load will be:

Capital charge	.0156 per K.W. Hour
Operating cost	.004 per K.W. Hour
Total	.0196 per K.W. Hour

Whether a single or a duplicate unit plant should be built for the purpose of supplying power to any given industrial manufacturing plant depends upon several factors:

1. Will the machinery be damaged if the plant is shut down.

2. Is the product of the plant sold up to 100% possible output.

3. Can the operation be made day or night without great increase in cost or decrease in the quality of product.

4. Is the product shipped directly from the mill or from warehouse—If from warehouse, a manufacturing shutdown does not mean a stoppage of shipping.

5. Can the plant operate with single or double shifts, either 8 or 10 hours long, thus permitting at least 4 hours per day for minor adjustments.

6. Effect on labor costs in plant when a short day is worked.

When all of the above factors have been carefully studied, it will frequently be found, and the writer feels much more frequently than is commonly supposed, that a power interruption either complete or in part, especially with advance notice, will mean very little in the yearly check-up of the profits of a rolling mill or other industrial plant. Wherever possible, full advantage should be taken of the capital charges which can be saved by using a single unit plant. Assuming the single unit plant, and that 6% interest on $250,000 (the additional cost needed to make it a duplicate plant) is put aside each year at compound interest, at the end of 10 years this would amount to $209,569 and, 3% annual depreciation on $500,000 which was originally invested compounded at 6% will be $191,436.86. The sum of these two items is $401,005 which is ample to replace all machinery in the plant.

The principle inllustrated above should be applied not only to the industrial plants, steel mills, etc., which build power plants to manufacture their own power, but should also be applied to contracts made with power companies for the purchase of power.

This means that there are a number of industrial plants that can operate satisfactorily with a power contract which permits the power company after due notice to curtail the amount of power which that plant takes on any day or even during certain hours of any one day. For instance, the consolidated peak load of the Philadelphia Electric Company and The Pennsylvania Power & Light Company systems in the winter months will begin at about 4:00 P. M. and extend until about 8:00 P. M., so that an industrial plant desiring to operate two shifts per day could very nicely end the day shift at 4:00 P. M. and start the night shift anytime after 8:00 P. M., thus avoiding entirely the peak load period of this large power system. In

other words, the industrial plant engineer together with the power engineer of the power company should work out the best possible power contract, taking into consideration not only the load factor of the industrial plant, but also the ability of the industrial plant to adjust its power demand in such a manner as to help improve rather than lower the power company's load factor. When this is done, the industrial plant is entitled to power rates considerably lower than when the power company contracts to supply power continuously throughout the 24 hours of every day and 365 days per year.

Power contracts taking these things into consideration will not only benefit the purchaser but also the power company, and if properly presented to industrial plant managers, should open up a field for the power salesman in which he otherwise cannot compete with privately owned power plants.

The plant manager should bear in mind when considering a power contract which permits the power company to reduce his load under certain conditions, that the power company makes profit only on the power sold, therefore, will not ask him to shut down any more than is absolutely necessary.

It should also be borne in mind that a firm power contract does not prevent storms or accidents from causing a sudden power interruption and in this respect there is little to choose between firm and secondary or restricted power contracts.

It is well to consider a firm power contract as comparable to a duplicate power plant and a secondary power contract as comparable to a single unit power plant.

The writer believes there are many types of mills, foundries, shops, etc., where the capital expense of only a single unit plant or a secondary power contract is justified.

The Contribution of Safety to the Iron and Steel Industry

By JOHN A. OARTEL*

THE improvements in the manufacture of iron and steel within the memory of those living today have been so many, so varied and have brought about such efficiency in production and increase of output as to almost approach the marvelous. These changes have been so apparent that they have eclipsed to a certain extent other changes as important and as far reaching that have to do with the human factor in industry.

On March 23, 1908, the General Solicitor of the United States Steel Corporation and of its Subsidiary Companies called a meeting of the Casualty Managers of the Subsidiary Companies to be held at his office on April 9th and 10th for the purpose of considering the results of the attempts which had been already made to prevent accidents and of considering and formulating further plans for the prevention of accidents and safeguarding employes. Judge Elbert H. Gary, Chairman of the Board of Directors of the United States Steel Corporation, gave his hearty indorsement of the purposes of the meeting as follows:

"Some of the gentlemen present, if not all of them, know that I am in hearty sympathy with the movement. We should like to take a prominent part, a leading part, in any movement and in every movement that is calculated to protect employes of the different corporations in which we are interested, and any requisition which is made for the expenditure of money to install equipment to protect our people will be honored. And I do not hesitate to say that we expect our legal departments, and the gentlemen who are subject to their control and direction and advice, to take such steps as are practicable to ascertain everything that can possibly be done at every locality and in every department to add to the safety of our equipment and to prevent accidents. Upon the ascertainment of the facts which enable the heads of departments to form an intelligent judgment we should be glad to have recommendations made so that we shall have an opportunity of finally passing upon the question involved. But there is not any doubt that our Corporation will promptly and fully approve every suggestion that is made for the betterment of the conditions in this respect, provided the recommendations seem to be practicable, if the only question involved is the question of dollars and cents; that is to say, we will not hesitate to make the necessary appropriations in money to carry into effect every suggestion that seems to us to be practicable for the improvement of the conditions at our mills, so far as the question of taking care of our employes is concerned."

This pronouncement of Judge Gary, made twenty years ago has resulted, according to a statement recently issued by the Bureau of Safety, Sanitation and Welfare of the Corporation, in the saving of 54,807 men from serious and fatal injuries during that time. If we add to that number the lives and limbs of men saved in other companies, we are led to conclude that Safety has indeed made a contribution to American Industry that ranks equally well with the increase in production and efficiency.

In addition to saving human lives and limbs Safety has contributed other things that have led thinking employers to conclude that accident prevention is a worthwhile endeavor.

1. Safety has done its bit in bringing about an increase in production with a reduction in costs in our industries as the following will illustrated:

*Chief of Safety Bureau, Carnegie Steel Company.

A bar mill in the Pittsburgh district in January of 1927 had a production record of 20,812 tons of bars with not a single lost time accident. In March of the same year 21,934 tons were produced, a gain of 1,122 tons over their previous best record and there was not a lost time accident during the entire quarter. A bloom mill, three large rolling mills rolling rails and one rolling sheet bar in the Pittsburgh district recently completed an entire year without a lost time accident. The bloom mill serves the three rail mills and the sheet bar mill. The rails rolled range in size from 12 to 130 pounds to the yard. During this period the bloom mill and one of the rail mills exceeded their best tonnage record. Neither was there any one injured during this period in the mechanical and electrical departments serving these mills.

2. Safety has also been an important factor in promoting better relations between employer and employe which is very essential if American industry shall continue to prosper and lead the world. No organization can be successful in which co-operation is lacking.

In Safety we have common ground for employer and employe and with both standing together on that common ground it is not difficult to take up other problems and solve them satisfactorily. The writer has been in hundreds of safety committee meetings in steel mills and manufacturing establishments and has seen superintendents, foremen and workmen sitting around the table discussing safety, a matter on which there was no argument. Then the group would separate and go to their respective positions; the superintendents to their desks, the foremen to assume the directing of the process, and the workmen to their jobs with the fine spirit of good fellowship, harmony and co-operation engendered in the meeting still prevailing. If production was to be speeded up, every man did his bit, and if other difficulties needed adjustment, it would be done in the same spirit.

Yes, Safety is a common meeting ground, a neutral zone, over which floats the white flag of peace. This being so, the employer, superintendent or foreman who will give Safety his honest and sincere support will find that it will pay handsome dividends.

3. In addition to the things already mentioned Safety disciplines the individual. If we could examine the reason for all the wars that have cursed this old world, we would find invariably that an individual or a group of people wanted more than his share of this world's goods or more property than rightly belonged to him. These selfish people, in the realization of their false ambitions, have left a trail of war, bloodshed, poverty and disease down through the ages. On the other hand when we consider the men who have blessed the world we find that they have been actuated by unselfish motives. They have considered the other fellow. The result of their unselfish consideration has been the designing of processes to make men's work easier, the search for remedies to cure and banish disease and the building of a social structure to make life happier and living more worth while.

In linking this thought up with Safety we are led to observe that in order to bring Safety to its fullest fruition we must necessarily think of others. The manager of the plant who plans Safety for his establishment will be obliged to think of his employes individually and collectively. They will pass in mental review and he will be led to consider their individual peculiarities. He will find that in order to put across a successful safety program certain adjustments will have to be made and some of them will perhaps be in his own character. He will find that he will need to practice some high class salesmanship in order to sell Safety to his organization. The salesman caters to his prospect and if necessary will become "all things to all men" to win them to the proper consideration of the article he sells. What does the selling of Safety result in? The inevitable result is that the manager becomes a bigger, a better and a broader man.

Along the same line the workman who supports Safety is careful, not only about his own actions, but in addition does his work in a manner that will keep his fellow workmen free from accidents.

And so, in Safety we have a mighty principle at work, we may even call it a divine principle that is slowly and surely transforming this country into a workman's paradise. Our captains of industry conduct their business not for gain alone, they are becoming more and more interested in the happiness, prosperity and safety of their employes. The men who man our great industries are not mere cogs in a wheel, as muckrakers have delighted to picture them. With an ever growing interest in the safety of themselves and their fellow workmen they do their work cheerfully and well. Their horizon is broadened and their outlook on life is entirely changed.

Electrification as a Means of Reducing Costs

By G. E. STOLTZ*

I DO not believe the Electrical Engineers in the Steel industry appreciate the effective work they have done in having the Steel industry adopt electrification. Their efforts have been concentrated so much on the problem itself that we doubt if they appreciate the importance of what is being accomplished.

Since the war practically every industry has been subject to a declining commodity market price. A composite price of steel products indicates that the market price of steel has dropped 25% since 1919. This is a very serious situation unless it is met by

*Mgr. Industrial Engineering Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

corresponding reduction in cost. One of the large items in the cost of manufacture of course is labor. Operators are not inclined to reduce wages but they have effected a reduction in the labor charge by the introduction of electrically driven labor saving devices. Since 1919 the Steel industry has increased the tonnage output per wage earner 56%. This is a very wonderful record and shows one of the real merits of electrification in its application to labor saving machinery. The Paper industry during this same period has increased their output per wage earner 31%. In the bituminous coal fields the output per wage earner has only been increased 17%, while in the anthracite field the output per wage earner is 13% less than it was in 1919. If the output per wage earner in the Steel industry had suffered a reduction of 13% since 1919 we believe the situation would be distressing.

Previous to the war and during the war period the membership of the Association of Iron and Steel Electrical Engineers gave the question of electrification a great deal of study and attention. This old question of steam vs. electric drive was discussed many times and was a topic that was brought to the attention of every engineer and executive in the Steel industry. At that time the application of electrical apparatus was largely made on the basis of a decrease in the cost of power over that obtained with steam engines. Of course the electrical engineers of our steel plants recognized there were other advantages than mere reduction in power costs, but at that time electrification had to be sold on power economy alone.

When new methods of manufacture are being introduced many of us are inclined to let our competitors do the experimenting while we retain our older methods. This in general is a mistaken idea as can be seen in the Steel industry. Some of our companies were very quick to adopt electrification and took advantage of the decrease in power costs. Those companies who have done this and have this experience behind them are meeting this declining market price for steel by the adoption of electrical apparatus to effect a reduction in their labor charge, to improve the quality of their product and to increase the tonnage output. As a matter of fact the possibility of economy along these lines is so great that the power saving need receive very little attention. As a matter of fact our steel companies are making greater expenditures for more elaborate electrical installations in order to effect these economies than they have in the past. An increase in tonnage output per wage earner of 56% in a short period of eight years is phenomenal and such installation as were made in the Homestead Works where the tonnage output per wage earner is six times as great as it was before the new electrical driven mills were installed cannot possibly be made with steam engine drive. Electrical apparatus can be selected with characteristics to suit almost any application. It is difficult to imagine any application that cannot be properly met with some type of electrical equipment having the proper characteristics built into the apparatus.

Our recent tandem strip and wide sheet mills would not be possible if it were not for the fact we can design and build into our electric motors and control definite characteristics which would not be possible with steam engine drive.

The steel companies today are reaping a great benefit as a result of the careful and continued study that the membership of the Association of Iron and Steel Electrical Engineers made of the advantages of electrification during the past years. When it became necessary immediately after the war to meet a constantly declining price market, the Iron and Steel Engineers were prepared to offer electrification as a method of meeting this new situation.

The Future of Safety

By FRANK H. ROWE*

IN the beginning the gods seeing the helplessness of man divided him into men so that he might be more helpful to himself. The philosopher speaks of One Man as being present to all men only partially or through one faculty and to find this man you must take the whole of society. He implies that the individual, to possess himself, must return from his own labor to embrace all of the other faculties of the original man.

The American Scholar

In the beginning of our Industrialism as we know it today, men were nearer the One Man than we of today. At the time Safety was first being organized by those pioneers of the Association of Iron and Steel Electrical Engineers, men were still nearer the One Man than we are today. To follow the implied dictum of the philosopher, that the individual to possess himself must return from his own labor to embrace all of the other faculties and labors of the Original Man is a physical impossibility and under present conditions could not be accomplished in the present span of life. When we say that men have worked their way from the bottom to the top of our industries, we speak allegorically. It would be better to say that they have jumped from the bottom to the top and that in jumping they have had to take much for granted along the line. In the old days before Industrial Man was so divided, it was possible for men to work up to the top. The One Man of yesterday no longer exists—we have today an array of specialized men in our industries. Space will not permit us to go through the many ramifications and divisions of the Industrial Man of today. We can, however get a general idea of what this division amounts to today, by going back twenty-five years and placing ourselves in Industry as it existed at

*Safety Director. Portsmouth Works, Wheeling Steel Corp., Portsmouth, Ohio.

that time, as a machinist. Starting at this late vantage point let us survey the many specialized jobs today that can be listed under the Machinist Trade. Formerly these jobs were all done by one man, but today each of these old jobs have been made trades of their own requiring special machinery and training. Without much trouble we can name fifteen special jobs, each of which carries the title of machinist. Using this same percentage in other trades and occupations, we gain a fair estimate of the many divisions of the Industrial Man of Yesterday.

What has been the result of this increase of specialized industrialism, as applied to general public? Has this breaking up of the One Man into so many men parts been for the good of the physical being of men? In answer to the first question, we must say that the results have been good, but we must say "No" as an answer to the second question, because the physical being of men has not kept pace with the kaleidoscopic changes in industry. Men are creatures of habit; and habits are formed slowly and once formed, are hard to change. Men have tried to adapt themselves to habits which coincide with the varying changes in industry, but they no sooner get started on habit changes for an industrial change, and another industrial change is made necessitating different habits. This constant changing produces hazards that industrial men are unable to entirely cope with. In these many changes, conditions are created which undermine the health of the various men exposed to them and in addition they are exposed to accident hazards due to improper habits used in the former condition. We can see no need of recounting the number of deaths and injuries due to accidents, nor the number of impaired beings due to the breaking down of their health, to prove this statement.

The conditions mentioned in the foregoing paragraphs are likely to continue because Industry does not want to slow down. As for Safety—we must adapt ourselves to the conditions as they exist in this particular time. We can no longer preach and work safety as we did a few years ago. If industry speeds up, Safety Work will have to speed up a little faster. We have accomplished much in the past; we are doing a good job now; there are still many converts to be made for Safety and men—there are some yet—who still think that accidents will occur no matter what is done to prevent them. These conditions exist everywhere in Industry and you who are of the supervisory force have them brought to your attention each day in some manner. It may be an accident, a request to lower your cost, the replacement of some employe or a dozen other things—individually or collectively they are the result of this great rush in Industry. If there are—and no doubt there are—accidents occurring from time to time to men who are under your supervision, why not apply the same methods to prevent the accident, that caused it. If too much speed has been introduced in your operations, or if radical changes have been made in the past few years, so that your employes have not had time to properly adjust themselves yet, why not speed up your safety work or make some radical changes in your style of doing it. You know some men still think that all that is necessary is to tell an employe "to be careful" and the safety program has been carried out. If the employe happens to get injured the foreman says, "I told him to be careful." On the other hand if the employes get along without an accident, the foreman says that it was accomplished by talking to the men. Some superintendents appoint safety committees and tell them to meet on a certain day and time for their safety meeting. That closes the safety committee business for him. He is too busy to attend a meeting now and then, but leaves the instruction of the committee to some one else. Even the foreman fails to consult the safety committee members and take an interest in what they are trying to do as a committee.

Perhaps all of this is old stuff—no doubt you have heard it before. We admit that it is old stuff. But it proves our point and that is that a lot of people are still trying to prevent accidents in an old fashioned manner. They are still using safety methods that they started out with fifteen or twenty years ago in an Industrial Era that has far outgrown these conditions. Bring your safety methods up to date, so that they will fit into the industrial scheme of things today. Put some speed into your safety campaign. Study your present conditions and make your safety fit in with them. Don't try the old method any longer. Make Industrial Safety Methods correspond to Industrial Production Methods of today and your safety record will improve and keep pace with the production record.

Make yourself the One Industrial Man of your department. Return from your specialized job and embrace a few of the faculties of the Safety Men and see what wonderful results you will obtain. The future of safety depends on how well you present it to the employes under your supervision. The old adage, "Nothing Risked, Nothing Gained" applies to the safety game today. Our Association of Iron and Steel Electrical Engineers is alive to these needs and has taken steps to further safety work by organizing a special division to bring out the necessary facts and information. Take part in your Safety Division program. Boost it! Specialize a little in Safety.

Convention Number

This June number is devoted entirely to the Annual Convention and Iron and Steel Exposition being held in Chicago during the week of June 25th to 28th, 1928. As you will have some two weeks time to read it over before the convention, we would appreciate it if you would come prepared to discuss at least one of the papers to be presented at that time.

Please bring this issue to the convention and technical session with you.

The Evolution of the Application of Electricity to the Manufacture of Steel

By GEORGE J. WALZ*

SINCE all old men are proverbially so fond of reminiscing, it is only natural, that there should often arise before my mind's eye, a picture of the steel plant, in which I first went to work, as a boy, a full one-third of a century ago. For it"s electric power station, I see a tiny shed containing one or two early type Brush series arc-lamp generators, and several diminutive Edison Bi-polar and Manchester type Dynamos, all belt-connected to reciprociting steam engines, and feeding through switches mounted on an all-wood switch-board. Outside of the power station, the only evidences of electricity were the strings of open-arc and carbon incandescent lamps, half a dozen electrically operated cranes, and, at most, half a hundred stationary motors driving fans, pumps and machine-tools, the largest of all the motors being a 75 hore-power motor on the hoist of an Open Hearth Ladle Crane. All other work around this plant, which, even at that time, was one of the very largest in the country, was performed by steam or hydraulic energy, or that most waste-ful and back-breaking power of all,—human muscle.

The Electrical Superintendent's task of striving to keep his electrical equipment in operation at that time, was a truly discouraging an dheart-breaking one, for both the motors and controllers, being early types, designed purely for operating small, light street cars, were totally incapable of standing up to the heat, dirt and abuse of steel plant service. The consideration of repairability had undoubtedly been entirely omitted in their design, partly because the apparatus was all so primitive and partly because street car equipment was intended to be repaired only in the shops. The slender force of "electricians" upon whom the Electrical Superintendent was constrained to depend for support was totally devoid of any training or experience, which would tend to qualify them for the work of trying to keep those antiques in reasonably continuous operation,—a task that would be truly impossible, even for the experienced crack steel mill electricians of today. These men in the old days were furthermore badly handicapped by the lack of any tools or shop facilities worthy of the name,—in fact, I distinctly recall one of those prehistoric electricians, whose entire kit of tools consisted solely of a cast-off carpenter's hatchet, with which he became quite expert at neatly cutting the then prevailing sizes of insulated and trolley wires.

Today, the picture presents an entirely different aspect, for the very same steel plant referred to above, possesses power stations containing units capable of generating a total of 25,000 kilowatts, with all the necessary switching, protecting and converting apparatus, modern and complete in every detail. This energy is generated at a cost, just about **one-tenth** of its cost in the early days referred to above, in spite of the marked increase of the material and labor costs entering into it, and it is transmitted throughout the works on huge towers, each one a small structural steel building in itself. This same works has now in regular operation over 2,400 D.C. and A.C. Motors, practically all designed especially for steel mill duty, and of every standard size and electric characteristic, ranging up to a 6,000 Horse-power continuous rating D.C. Reversing main roll motor.

In any number of operations throughout the plant, the vanishing uneconomical muscle-power is today making its hopeless last stand against the omnipotent little push-button. Consider, for instance, the work of "making bottom" in an Open Hearth Furnace. In the days of the twenty-four hour turn this job was a real man-killer, for the man performing it was forced to stand directly in the blistering heat of the open furnace door and throw the dolomite with a shovel, as far into the hot furnace, as possible. In order to reach the area of the bottom beyond the range of his shovel, it was necessary to put the dolomite on an extremely heavy, long-handled steel spoon, push this to the back of the furnace, turn it over, and pull it out again. Today, this same operation is performed electrically by a machine (which by the way has replaced twelve men) having one motor which moves it along a track in front of any particular furnace-door and annother motor, driving a belt, which actually shoots the dolomite to any part of the largest furnaces;—all the operator has to do is to aim the stream in the proper direction.

Another operation, which, until recently, was just about as soft as the regular daily grind of an ancient galley-slave, was the turning over of rails by hand, as they were being fed through the straightening press. One of these standard tee-rails weights three-quarters of a ton (some girder rails weighing as much as a ton and a half each) and was turned manually with a bar three feet long, having an open jaw at one end, which was slipped over the base of the rail. Today, the rail is rotated by a motor, controlled entirely by the feet of the straightening press operator.

Another particularly noticeable innovation is the virtual extinction of the hordes of laborers pushing wheel-barrows, they having been replaced by innumerable portable motor-driven belt conveyors, this change being followed recently by the most revolutionary one of all, which put an electrically refrigerated drinking fountain serving filtered water, in the place of the time-honored old water-bucket.

Now, to the casual observer, it might appear from the above, that this particular steel plant, which is assuredly a typical one, is practically entirely electrified, and as far as mechanicaly operations are concerned this is true, for in this field, the steam yard-locomotives and locomotive cranes are the only major units, which are not as yet electrically operated.

*Asst. Elec. Engr., Bethlehem Steel Co., Steelton, Pa.

So, it would appear, that, while in the future there is still some hope for lesser improvements and extensions in mechanical operations, it is in the field of metallurgical processes and operations that the real opportunities for the further expansion of the application of electricity in the manufacture of steel products undoubtedly lie. In this metallurgical field, a great deal has, without doubt, already been accomplished by means of electricity, such as the manufacture of high-grade steel in electric furnaces, the rapidly increasing use of electricity for generating heat in innumerable different applications, and the marked progress being made todfay in the use of the electric welding arc., in both the manufacture and reclamation of steel products.

Yet, if we were to be allowed to look ahead another third of a century and see the plant referred to above, I venture to say, that we would probably see a plant whose electrical power cost, compared to the present one, would be riidculously low, due to the use of much higher steam pressures, larger units and many other economies, which it is difficult to foresee now,—but one of which might easily be the tapping of the unlimited heat-supply under the earth's crust. We would then see a plant, which mainly on account of the insignificant cost of this power, and its use in off-peak periods and improvements in its application, would be equipped with electrically operated blast furnaces, open-hearth furnaces, soaking pits and heating furnaces, or it is altogether possible, that the ferrous metals will by that time be made entirely by direct electrolytic of electrochemical processss, but in ither case this will mean the final realization of the Steel Mill Electrical Engineer's Dream, "A truly 100% Electrically Operated Steel Plant."

Stevens Hotel, Chicago, Ill., where Iron and Steel Exposition will be held.

LIST OF EXHIBITORS

At

IRON AND STEEL EXPOSITION

HOTEL STEVENS - - - - CHICAGO ILL.

JUNE, 25-28, 1928

Alliance Machine Co. 29
Allis-Chalmers Mfg. Co. 54–56
Appleton Electric Company 81
Aluminum Co. of America 49

Bristol Company 152–153–154
Baker-Raulang Company 51–53
Bussmann Mfg. Co. 70
Bartlett Hayward Company 100
Benjamin Electric Mfg. Co. 108
Bulldog Electric Products Co. 149

Chapman-Stein Co. 114
Crocker-Wheeler Elec. Mfg. Co. 3
Cutler-Hammer Mfg. Co. 71–73–75
Clark Controller Co. 103–105
Colts Patent Fire Arms Mfg. Co. 131
Chicago Fuse Elec. & Mfg. Co. 132
Crouse-Hinds Company 148–150
Philip Carey Company 113
Cutter Elec. & Mfg. Co. 1

John C. Dolph Company 26
M. H. Detrick Company 60

Economy Fuse & Mfg. Co. 7
Electric Controller & Mfg. Co. 27–28
Electric Journal 30
Edison Storage Battery Co. 34
Electric Storage Battery Co. 40
Electrical Engineers Equipment Co. 45
Elliott Company 143
Erie Malleable Iron Co. 52
Electric Service Supplies Co. 61
Electric Machinery Mfg. Co. 22

Freyn Engineering Co. 102
Fairbanks Morse Company 133–135
D. B. Flower Mfg. Co. 109

G. & W. Electric Specialty Co. 6
Green Equipment Corp. 46
General Electric Co. 86-7-8-9-90-91

Hagan Corporation 57
Hyatt Roller Bearing Co. 58–59
Hodson Corporation 76
Holophane Company 111

Ideal Commutator Dresser Co. 130
Industrial Engineering 84
Iron & Steel Engineer 156
ITE Circuit Breaker Co. 1
Ivanhoe Division of Miller Co. 107

Johns-Manville Corp. 151
W. J. Jeandron 146

Keystone Lubricating Co. 41–43

Lincoln Electric Co. 134
Lapp Insulator Company 44
Le Carbone Brush Company 146

Metal & Thermit Corp. 35
Monitor Controller Co. 55
Morgan Engineering Co. 79
Manning Maxwell & Moore, Inc. 82
Martindale Electric Co. 85
Henry N. Muller Co. 6

Norma-Hoffmann Bearings Corp. 4
National Carbon Company 8
National Air Filter Co. 50
Nichols Lintern Co. 155
R. D. Nuttall Company 115
New Departure Mfg. Co. 142
National Lamp Works of G. E. Co. 110

Otis Elevator Company 23-24–25
Ohio Electric & Controller Co. 101
Okonite Company 147

Pittsburgh Elec. & Machine Works 2
B. F. Perkins & Sons 9–10
Pyle-National Company 77

Reliance Electric & Engr. Co. 12-3-4-5-6-7-8-9-10-21
Robinson Ventilating Co. 33
Rockbestos Products Corp. 47
Rollway Bearings Corp. 138
Rowan Controller Co. 140
Roller-Smith Co. 141
Republic Flow Meters Co. 139
Reed Air Filter Co. 48

Schweitzer & Conrad 5
SKF Industries, Inc. 72–74
Square D Company 83
Standard Underground Cable Co. 136–137
Steel Publications, Inc. 22
Shaw Crane Putnam Machine Co. 82

Timken Roller Bearing Co. 32
Tool Steel Gear & Pinion Co. 78–80
Thompson Electric Co. 106
Harold E. Trent 104
Trumbull Elec. Mfg. Co. 144–145

United States Graphite Co. 42

V. V. Fittings Co. 31

Edwin L. Wiegand Co. 104
Westinghouse E. & M. Co. 116-7-8-9-20-121
Wheeler Reflector Company 112

INDEX TO ADVERTISERS

A

Alliance Machine Company 344
Allis-Chalmers Mfg. Company 429
American Heat Economy Bureau 355
Aluminum Co. of America Cover 3
Appleton Electric Company 341–342
Automatic Reclosing Circuit Breaker Co. 428

B

Bartlett Hayward Company 375
Benjamin Electric Mfg. Company 358
Blaw-Knox Company 361
E. W. Bliss Company 356
Boxill-Bruel Carbon Co. 371
Bristol Company 328–329
Bussmann Manufacturing Company 401

C

Chapman-Stein Company 431
Chicago Jefferson Fuse & Elec. Co. 359
Clark Controller Co. 316-317-318-319-320-321-322-323
Cleveland Crane & Engineering Co. 399
Colts Patent Fire Arms Mfg. Co. 389–394
Condit Electrical Mfg. Corp. 354
Copperweld Steel Company 394
Crocker-Wheeler Electric Mfg. Co. 315
Crouse-Hinds Company 334–335–336–337
Cutler-Hammer Mfg. Co. 338–339

D

Delta Star Electric Company 395
De Laval Steam Turbine Co. 388–391
M. H. Detrick Co. 433-434-435-436-437-438-439-440
Doubleday-Hill Electric Co. 397
Duquesne Light Company 420

E

Economy Fuse & Mfg. Co. 411
Electric Controller & Mfg. Co. 346
Electric Machinery Mfg. Co. 418
Electric Power Equipment Corp. 370
Electric Service Supplies Co. 365
Electro Dynamic Company 410
Electrical Engineers Equipment Co. 390

F

Farrel-Birmingham Company 377
Freyn Engineering Company 348

G

Gears & Forgings, Inc. 432
General Electric Co. Cover 4–332–333
Graybar Electric Company 392

H

George J. Hagan Company 413
Harnischfeger Corporation 427
Hyatt Roller Bearing Company 340–343

I

Ideal Commutator Dresser Co. 390
International Combustion Engineering Co. 353
Iron City Electric Company 393
ITE Circuit Breaker Co. Cover 1
Ivanhoe Division of Miller Company 430

J

W. J. Jeandron 400
Johns-Manville Corp. 367

K

Keystone Lubricating Company 352

L

Lapp Insulator Company 372

M

Martindale Electric Company 357
Mesta Machine Company 374
Moloney Electric Company 419
Monitor Controller Company 378
Morgan Construction Company 392
Morgan Engineering Company 360
Morganite Brush Company 426
Henry N. Muller Company 389

N

National Air Filter Company 387
National Carbon Company 347
New Departure Mfg. Co. 415
Nichols-Lintern Company Insert 379 to 386
Norma-Hoffmann Bearings Corp. 373
R. D. Nuttall Company 404

O

Ohio Electric & Controller Co. 350
Okonite Company 422
Otis Elevator Company 364

P

Pittsburgh Carbon Brush Co. 368
Pittsburgh Electric & Machine Works 330–331
Pyle-National Company 405

R

Railway & Industrial Engineering Co. 412
Reliance Electric & Engineering Co. 345
Republic Flow Meters Company 324–325
Robinson Ventilating Company 417
Rockbestos Products Corp. 363
Roller-Smith Company 391
Rollway Bearing Company 402
Rowan Controller Co. 366
Rumsey Electric Company 403

S

Sharples Specialty Company 396
Shaw Crane-Putnam Machine Co., Inc. 424
Shepard Electric Crane & Hoist Co. 406
SKF Industries, Inc. 423
Smith & Serrell 395
Square D Company 425
Stackpole Carbon Company 376
Standard Underground Cable Co. 369
Stimple & Ward Company 414

T

Thompson Electric Company 362
Timken Roller Bearing Company 407
Tool Steel Gear & Pinion Co. 398
Trico Fuse Mfg. Co. 408–409
Trumbull Electric Mfg. Co. 416

U

United States Graphite Company 421

V

V. V. Fittings Company 351

W

Weston Electrical Instrument Corp. 388
Westinghouse Electric & Mfg. Co. Cover 2–326–327
Edwin L. Wiegand Company 349

*Yearly Review Electrical Developments Iron and Steel Industry**

By W. H. BURR†

IN the January issue of the Iron and Steel Engineer each year a revised list is published showing all the Electric Drives on Main Rolls in the Steel Plants of the United States and Canada.

The Electrical Development Committee will make no attempt to elaborate on this list but will call your attention to some of the outstanding facts.

In 1920, the Electrical Development Committee reported forty-four motors driving Reversing Mills and one-hundred and thirteen mills of various types on which electric motors had been installed, making a total of one-hundred and fifty-seven motors on main roll drives at that time. In January, 1928, there were reported over fifteen-hundred main roll drive motors in United States and Canada.

During the year of 1927, there were purchased one-hundred and twenty-two main roll drive motors ranging in size from 300 HP to 7000 HP. Of this number, sixty-three were DC motors, forty were 60 cycle, seventeen were 25 cycle, and two were 50 cycle motors. More than half of the motors were DC motors, a condition quite different from that existing a few years ago. Eighty of these motors were used in connection with gear drives, which is evidence that the modern reduction gear has proven its reliability to the satisfaction of the steel mill industry.

Main Roll Drives

A review of the main roll motor installations made in steel mills in 1927 shows that a large number were used to drive continuous strip mills and today this is one of the most active improvements under consideration by the steel trade generally.

The rolling of wide thin strip steel requires very highly powered mills and the tendency has been very decidedly toward individual drive for the various roll stands.

High speed tandem and continuous mills require roll drive motors which have a minimum amount of speed regulation in order to insure successful operation of the mill. Direct current motors are used almost without exception for mills of this class.

The past year has witnessed the placing in operation by the American Sheet & Tin Plate Co. of one of the heaviest power tandem hot strip mills in the country. This mill is located in the Chicago district and the six finishing stands are driven by individual 2500 HP, 40°C. rise, 160/320 RPM, 600 volt, direct current, adjustable speed motors. Power for the 2500 HP motors is supplied from three 3000 KW, three-unit synchronous motor generator sets operating in parallel.

One 3000 KW set is used to start the six 2500 HP motors by means of variable voltage control. The operation of all main roll drive motors is controlled from an operator's pulpit desk located in the mill and on the opposite side of the mill from the main sub-station.

There is now under construction for the American Rolling Mills Co., in the Cincinnati district, a hot strip mill which will be equipped with motors somewhat larger than those mentioned above, making it the largest capacity mill of this type in this country. The total main roll drive horsepower for the mill is 21,800 HP, which includes both AC and DC main roll drive motors.

The roughing stands are driven by two 800 HP, 14 pole, one 1000 HP, 12 pole, and one 1200 HP, 10 pole wound rotor motors. The motors have been designed so that mechanically the individual parts of the motors are interchangeable one with the other. This arrangement only necessitates a spare rotor with shaft and a spare stator, due to the fact that these parts can be placed on any of the bases and bearings due to the mechanical interchangeability.

The three intermediate stands are driven by individual 2000 HP, 600 volt, 300/500 RPM, direct current, adjustable speed motors.

Each of the four finishing stands is driven by a 3000 HP, 180/360 RPM, 600 volt, DC, adjustable speed motor.

The main roll drive direct current motors are supplied from three 4000 KW, three-unit, synchronous motor-generator sets operating in parallel. The auxiliary motors are supplied from two 750 KW synchronous motor- generator sets and the excitation for all main roll drive DC motors and generators is supplied from a 300 KW synchronous motor generator set.

The 6600 volt AC control consists of a total of 39 steel clad, truck type, oil circuit breakers. The main control switchboard consists of 34 dead front steel panels on which are mounted meters, relays, control switches, etc., for the station operation of all equipment. There is also a 63 slate panel board on which are mounted all air circuit breakers, knife switches, contactors, etc., for the control of all 600 and 250 volt DC and 2200 volt AC auxiliary circuits.

Two steel pulpit desks are mounted in balconies overlooking the mill from which the eleven main roll drive motors, ten table motors and other auxiliary equipment are controlled.

Power for the entire mill is purchased at 66,000 volts and stepped down to 6600 volts through two 12,000 KVA transformer banks, each bank consisting of three 4000 KVA single phase transformers. Each transformer is provided with flanges and valves so that at a later date radiators can be added in order to increase the rating of each transformer to 6000 KVA.

Mills recently purchased for the Cleveland district include eleven main roll drive motors of the latest design of construction, ranging in size from

*To be presented at A. I. & S. E. E. Annual Convention, June 25-28, 1928.

†Chairman, Electrical Development Committee. Elec. Supt., Lukens Steel Co., Coatesville, Pa.

400 to 1200 HP and a total of 6050 HP, continuous capacity for both mills.

Due to the high delivery speeds, close center distance stands and wide speed range of the motors, it was necessary to incorporate special design features in both motors and control to maintain the correct speed relation between adjacent stands so that stretching and buckling of the metal between stands will be eliminated.

The motors in one of the mills is supplied from a 1000 KW, 600 volt synchronous motor-generator set complete with direct connected exciter. The exciter supplies the excitation for the main roll drive DC motors and generators. The larger mill is supplied from a 4000 KW, three-unit synchronous motor-generator set including a direct connected exciter. The exciter supplies the excitation from the main roll drive DC motors and generators. The auxiliary motors are supplied from a 300 KW, 250 volt synchronous motor-generator set which is located in one of the main motor room substations.

There has recently been purchased for the Birmingham district main roll drive motors for a rod mill installation which includes five 6600 volt, 60 cycle, synchronous motors ranging in size from 1300 HP to 2750 HP and totaling 9650 HP. The synchronous motors are all designed so that they can be started by applying full voltage to the terminals of the motors with the exception of a 2750 HP motor. In order to reduce the starting KVA taken from the power system, to a satisfactory value, reactors are used in connection with the starting equipment for the 2750 HP motor.

The finishing stand for the rod mill will be driven by a 1200 HP, 230 volt, 520/575 RPM, direct current, adjustable speed motor. Power for the 1200 HP DC motor is supplied from a 1000 KW generator which is driven by a 2100 HP motor, which also drives a portion of the mill stands. The combination generator and mill drive represents a new feature for this class of service.

The synchronous motors purchased for the proposed installation mentioned in the preceding paragraph represent the first large synchronous motors to be applied on a mill of this class.

A reversing motor mill equipment has recently been installed in the Pittsburgh district which includes a new and novel feature in the motor generator set. This set is driven by a synchronous motor which has special features, making it suitable for the frequent heavy load demands.

There has recently been purchased by the Illinois Steel Co. for installation in the Chicago district a 6500 HP, 0/60/140 RPM, single unit reversing mill motor for the electrification of an existing steam engine driven mill. A new pinion housing and the motor will be installed on the opposite end of the mill from the present drive which will reduce the shut-down period of the mill during the change over to the minimum, due to the fact that the entire equipment can be installed with the mill in service.

One of the recent improvements in the mechanical features for electrical equipment has been incorporated in this equipment. The individual bedplate for both the reversing motor and the flywheel motor generator set are of the "built up" welded steel construction.

A 4600 HP, 40° C. rise, 700 volt, single unit reversing mill motor for driving a 35" roughing mill has been purchased for installation in India (Jamshedpur). The motor will be supplied by a flywheel motor generator set which includes two 1900 KW, 40° C. rise, 490 RPM, DC generators. These generators indicate that continued progress is being made in developing larger generator capacity at higher speeds for reversing mill service.

There has recently been placed in service by the Carnegie Steel Co., in the Youngstown district, a 4000 HP, 450 RPM synchronous motor for driving a 24" continuous billet mill. The motor represents the latest design in synchronous motors for this class of service in that the motor has a completely fabricated welded frame and bedplate.

A reduced voltage starting scheme is used to start the motor referred to in the preceding paragraph. In order to reduce system disturbances to a minimum and also to fully protect the motor, the starting scheme also includes a continuous torque feature which permits the motor to develop torque during the entire start cycle. The scheme also assures that the maximum starting and pull in torques are derived from the motor in order that the starting cycle may be completed in specified length of time.

A cold strip mill for the production of wide material was placed in operation by the American Rollings Mills Co. during the last year in the Cincinnati district. The mill is driven by five 600 HP, 400/800 RPM, 230 volt, direct current, adjustable speed motors.

For use in connection with this installation there was developed and perfected a special screw-down drive, so that each screw can be motor driven independent of the other screw. If it is desired to operate both screws at the same time a magnetic clutch is energized which causes both screws to turn at the same rate. An inching arrangement is also provided which allows the screws to travel one revolution and then stop automatically.

About the middle of last year the Trumbull Steel Company completed the remodeling of its 16-inch hot strip mill which was first placed in operation during 1918. The mill is now laid out for continuous rolling and will produce strip up to 36" wide. The driving power applied to the mill was increased by one new 5000 HP adjustable-speed Scherbius controlled induction motor, so that the total capacity of driving motors is now 13,000 HP. With the exception of one 300 HP and two 100 HP edger motors which are adjustable speed direct current machines, all the driving motors are of the slip ring induction type with speed adjustment obtained by the Scherbius system. The four horizontal roughing stands are driven by a 1500 HP motor, and each of the last three stands is driven by a 2000 HP motor. The speed of each motor can be adjusted between 270 and 450 RPM.

The Scherbius speed regulating set used with the 5000 HP motor is of especial interest as it is the first application using two alternating current commutator type machines in series. This design permits the use of smaller and higher speed units, and the higher regulating voltage obtainable permits of designing the induction motor with a lower secondary current. In this particular case, the two com-

mutator motors are direct connected to a 1175 HP synchronous motor forming a three-unit set.

Another large strip mill recently placed in operation is that of the Weirton Steel Company, at Weirton, West Virginia. This mill will produce strip up to 48" wide. There are eleven driving motors totaling 16,600 HP. The three driving motors on the roughing stands are 1500 HP, 6600 volt alternating current machines, one of which operates at 200 RPM and the remaining two at 450 RPM. There are three edger motors, each 200 HP, 400/800 RPM direct current. The five finishing stands are individually driven by two 2000 HP, 200/400 RPM and three 2500 HP, 200/400 RPM, 600 volt, DC motors. Power for the direct current machines is obtained from two synchronous motor generators, each consisting of two 1500 KW, 600 volt, direct current generators driven by one 4200 KVA, 0.8 p.f. 6600 volt synchronous motor. The five direct current motors are started simultaneously by control of the voltage of the four direct current generators.

Two large mills of the continuous type for rolling skelp have been placed in operation during the past year. One is at the Benwood, West Virginia, plant of the Wheeling Steel Corporation. This mill is provided with eight driving motors, all of which are adjustable speed, direct current machines. There are four edger motors, three of which are 50 HP and one 150 HP. These machines are operated from the 230 volt machines, power being supplied to them from a three unit motor generator consisting of two 2000 KW, 600 volt generators driven by one 5600 KVA, 4000 volt, 60 cycle, synchronous motor. The first two stands are driven by a 500 HP, 180/360 RPM motor and the remaining eight stands by three 2000 HP, 200/400 RPM machines.

The other skelp mill referred to is a 27"-24"-21" continuous mill installed by the Bethlehem Steel Company at their Sparrows Point plant. In addition to producing skelp, this mill is also designed to roll sheet bar. There are four main driving motors. The first is a 4000 HP, 83 RPM, 6600 volt, synchronous motor which drives the roughing train. The intermediate train is driven by a second synchronous motor rated 6500 HP at 187 RPM. The third is a 6700 HP slip ring induction motor with speed adjustment between 250 and 500 RPM obtained by the Scherbius system. Incidentally, this is the largest Scherbius equipment in the world. The driving motor on the last stand is a 600 volt DC machine rated 2600 HP at 275 to 320 RPM.

A unique feature of this installation is the method of tying together the Scherbius regulating machines for the 6700 HP induction motor and the direct current generator which supplies power to the 2600 HP finishing stand motor. This is accomplished by a motor generator consisting of five units, namely, the two regulating machines (R1) and (R2), a synchronous motor (S), a direct current generator (G), the 2600 HP DC motor, and the 4000 and 6500 HP synchronous motors on the roughing and intermediate stands. The synchronous speed of the 6700 HP induction motor is 375 RPM with speed adjustment above synchronism to 500 RPM and below synchronism to 250 RPM. When running below synchronism, the slip energy from this motor passes to the regulating machines (R1) and (R2) and the machines acting as motors assist the synchronous motor (S) in driving the current generator (G). If (G) were not supplying power to the finishing stand motor, the slip energy would be returned as electric power to the incoming line through the synchronous motor (S). However, when the finishing stand motor is loaded, the slip energy is available to drive this machine wholly or in part by supplying the driving power for generator (G). If the induction motor is required to run at speeds above synchronism the regulating machines (R1) and (R2) act as generators and the synchronous motor (S) draws from the incoming power line the energy which these machines and direct current generator and exciter require.

From the standpoint of the total horsepower involved, the new electrically driven beam mill for the production of wide flange structural shapes at the Lackawanna plant of the Bethlehem Steel Company is one of the most most highly powered mills in this country. The complete equipment consists of three units: a 54-inch reversing blooming mill, a 48-inch intermediate mill, and a 48-inch finishing mill. The finished sections are produced without any reheating of the steel from the time the ingot is removed from the soaking pit. The ingot is first rolled in the blooming mill to an "H" shaped bloom with a web from seven to twelve times the thickness of the web of the finished section. This bloom then passes to the intermediate mill which consists of two separately driven stands of rolls. One stand, known as the supplementary mill, has two horizontal rolls, and the main stand has two horizontal and two vertical rolls. The "H" shaped bloom enters this intermediate mill with the web horizontal. The supplementary rolls act only on the top and bottom edges of the flange. The horizontal rolls of the main mill effect the reduction in cross section of the web while the vertical rolls reduce the cross section of both flanges. In the main mill the driving power is applied only to the horizontal rolls, the vertical rolls rotating due to their contact with the beam.

After several passes back and forth through the intermediate mill, the beam passes on to the finishing mill which also consists of two stands, a main and supplementary, where several finishing passes are made.

The electrical equipment which was furnished for these mills is of particular interest. In the first place, the motor for driving the 54-inch reversing blooming mill is the largest single-unit direct current rolling mill motor which the General Electric Company has ever built. It is rated 7000 HP continuously-50° C. rise at 40/80 RPM. This motor is capable of exerting a maximum torque of 2,400,000 pounds at one foot radius. Direct current power is supplied from a flywheel motor generator consisting of one 5000 HP, 275 RPM, 6600 volt induction motor, one 50-ton flywheel, and two 3000 KW, 750 volt generators which are operated in parallel. This 54-inch blooming mill is one of the two largest reversing blooming mills in this country.

The electrical equipment for the intermediate mill consists of two reversing motors, one of which drives the supplementary rolls and the other the main rolls. The main roll motor is rated 7000 HP continuously at 50° C. rise, 65/125 RPM; the supple-

mentary mill motor is rated 1500 HP continuously at 50° C. rise, 65/225 RPM. The flywheel motor generator which furnishes power to these reversing motors consists of a 5000 Hp, 375 RPM, 6600 volt induction motor, duplicate of that on the blooming mill set, two 3000 KW generators for the main motor, one 3000 KW generator for the supplementary motor, and one 50-ton flywheel. This set is a duplicate of the blooming mill set except that it has three generators instead of two.

The finishing mill equipment is the same as that for the intermediate mill.

The total capacity of the main equipment for the blooming, intermediate, and finishing mills is just about 71000 horsepower.

The Bethlehem Steel Company placed an order for new electrical equipment for the Lackawanna rail mill. Engine drives will be discarded and the layout of the mill will be changed. It will consist of a 44-inch reversing blooming mill, the driving motor for which will be rated 7000 HP, continuously, 50° C. rise, at 50/120 RPM. Blooms from this mill will go direct to a 36" reversing roughing mill which will be driven by a direct current motor, rated 5000 HP, continuously, 50° C. rise, 50/120 RPM. Power for these two reversing motors will be obtained from a single flywheel motor generator consisting of one 8000 HP, 375 RPM, 6600 volt induction motor, two 3000 KW, 375 RPM, 750 volt generators operating in parallel to supply power to the 7000 HP blooming mill motor, two 2200 KW, 450 volt generators operating in series to supply power to the 5000 HP roughing mill motor, and one 75-ton flywheel.

The increasing use of synchronous motors for main roll drives is noteworthy. Sevent motors sold by the General Electric Company during the year 1927 totaled 12,600 HP. The largest of these is rated 5000 HP, continuously, 40° C. rise, 100 RPM, 2200 volts, and is used to drive a 19-inch continuous sheet bar mill at the Kokomo (Indiana) plant of the Continental Steel Corporation.

A motor of the same horsepower rating but at 240 RPM is used to drive a 51-inch piercing mill installed by the Standard Seamless Tube Company at Ambridge, Pa. This is the largest seamless tube mill drive in the world.

The remaining five motors, two of which are 400 HP and three 600 HP, drive copper and brass rolling mills.

The Standard Seamless Tube Company has also placed in operation a 32-inch reversing bar mill which is driven by a 2150 HP, 43/85 RPM, 550 volt direct current motor. Power for this motor is derived from a synchronous motor generator consisting of a 4200 KVA, 2200 volt synchronous motor, direct connected to two 1000 KW, 275 volt, direct current generators operating in series. This is the first installation of a reversing rolling mill motor deriving its power from a synchronous motor driven generator.

At the Union Plant of the Bourne Fuller Company, in Cleveland, Ohio, a 10-inch merchant mill has recently been placed in operation which, from the standpoint of the electrical equipment, is of particular interest. The mill has eight driving motors totaling 3400 HP. Five are 500 HP, 267/800 RPM, 230 volt, direct current machines and three are 300 HP with the same range of speed adjustment. The four stands which are driven by the three 300 HP motors and one of the 500 HP motors are in tandem and placed on very close centers, so that the metal being rolled is in all four stands simultaneously. For this reason, special provision has been made in the control provided for these four motors to reduce the speed regulation (that is, the change in speed from no load to full load) of each machine to a minimum and to maintain within close limits the relative speeds of all four machines.

There was installed in the plant of the National Tube Company at Lorain, two 3000 HP, 6600 volt, 25 cycle, 3 phase, 250 RPM synchronous motors driving Piercing Mills and one 1500 HP, 6600 volt, 25 cycle, 3 phase, 62½ RPM synchronous motor in the Gary Tube Company plant driving a Tube Mill.

Cranes

Most of the crane builders during 1927 have not developed any new way of handling steel, but the tendency has been to change the design of their standard machines to make them more serviceable both as to efficiency and cost of maintenance.

In featuring improvements to old equipment made during 1927, one of the builders of cranes outlines them as follows:

One Piece Steel Casting Trolley

Castings of this design have been made up to 75 tons capacity equipped with main and auxiliary hoists.

The advantages of one piece casting are: rigid construction, permanent alignment of bearings, low cost of maintenance, and long service.

During 1927, 24% of cranes were built with one-piece steel casting trolley.

Anti-Friction Bearings

During 1926, 7% of the cranes built by this company were of the anti-friction bearing design. During 1927, 25% of the cranes built were of the anti-friction bearing design.

Bearings used are mainly of the roller type as against the ball-bearing type.

Worm Drive Motions

This, the newest feature of crane design, as applied especially to mill type cranes, is being well received. In 1926, 1% of the cranes built by this company were equipped with worm drive for some motion and in 1927, 13% of the cranes built by this company were equipped with worm drive for one or more motions.

Welded Fabrication

In the matter of welding of structural material, this company welds all footwalks, crane cabs, and all miscellaneous structural parts. However, in the case of crane girders, they do not feel that the welding process has progressed far enough to warrant the fabrication by welding, both from the standpoint of efficiency and cost.

Heat Treated Track Wheels and Gears

This feature has been a very important one in the design of cranes for the year 1927 and its advantages are obvious and need not be discussed.

In our report last year we stated that one manufacturer of Steel Mill cranes had about forty-five cranes in operation equipped with roller bearings.

Records show that this list has been increased to about seventy-five cranes in operation with roller bearings.

A crane builder in the Ohio district recently shipped two 75 ton cranes which were not unusual except as to span, the span of these cranes being 120'. This span naturally necessitated very heavy girder construction, the girders being between 10' and 11' deep at the center, and the weight of two girders was about 185,000 lbs.

For some time this same crane builder has been working on a plant and has practically completed a successful design for an attachment to a regular screw type stripper which will strip inverted type molds as well as the regular type. From the interest being shown in this arrangement it is believed that there will be a large field for an installation of this kind for, as stated above, it will handle both types of molds.

Auxiliary Motors

During the past year, there has been considerable activity throughout the whole industry in the development of a motor that has all of the good characteristics of an enclosed motor with its freedom from dirt and moisture combined with the advantage of an open motor in that the expense is only slightly greater than the expense of a corresponding rated open motor. This result is accomplished by enclosing the active parts of the motor, including the air gap of induction motors, circulating the internal air so that the heat is carried away from the windings and given up by the air to thin walled heat conducting parts. The heat is removed from these thin walled heat conducting parts by an extremely active circulation of air drawn from the outside by especially designed fans. The expense of this type of motor is much less than the expense for fully-enclosed motor without these new features of ventilation, but of course, is somewhat more than the price of a corresponding frame for open rating due to the additional parts which are supplied.

The use of individual direct current drive on wire blocks has rapidly increased. Between 350 and 400 blocks have now been installed with such a drive. The principle advantages are the flexibility of the individual drive since the wire block may be operated at any speed desired for the particular work in hand; the smooth easy start that can be secured with direct current and the consequent control advantages in starting the wire through the die; the safety features which may be introduced with direct current motors and control. It is also very much easier to break in new operators when the block on which they are working is equipped with the direct current motor and control permitting of the very slow speed in drawing.

Where adjustable speed has been desired, cooling bed tables which usually have been driven by mill type motors have been installed, driven by general purpose, water-tight, field weakening motors.

Individual Drive for Rollers has been extended widely during the last year. One of the most successful is the installation of individual drive of rollers by motors where the motor is installed inside of the roller with the stator winding stationary on a fixed shaft, the squirrel cage and rotor core mounted on the inside of the shell but the outside of the stator so that when power is thrown on the motor roller, the roller revolves. There are decided advantages in this construction in that misalignment is impossible and a very considerable reduction in power results as compared to the conventional gear type table. It is also possible to install in much less space. Between 150 and 200 of these motor rollers have gone into operation during the past year and without a single day's delay due to failure of the motor rollers.

A new addition to a line of Induction Motors is now on the market known as **"Across-the-line"** type of motors **without end rings.** The new simplified construction of these motors enables them to meet the Starting Current requirements of central stations without the use of reduced voltage (compensator type) or resistance starters and also gives excellent results and performance characteristics under actual running conditions.

Control

A centralized switchboard control has been developed for air blast valves on blast furnace plants. The use of motor operated valves in air blast lines from the blowers which furnish air for the blast furnace is a rather recent application. These valves are large and difficult to operate by hand and are frequently rather inaccessible. If operated by hand, it requires several men from 30 minutes to 1½ hours to shift the blast from one blowing unit to another. When motor operated, this shift can be made by one operator in a few minutes' time.

The control for the motor operated valves is preferably centralized on a convenient control switch board under the supervision of the Blower Operator. This switchboard may be furnished in unit sections as required and units added as the plant and equipment is expanded. A mimic piping system is laid out on the switch board showing all the blowing units, location of the valves, cross connections and main headers. Each valve control station is mounted in this mimic system at the location of the valve and the indication lights of the control stations show at a glance which valves are open and which are closed, enabling the operator to see clearly the various paths of the air in the blast system. It is a matter of only a few seconds for the operator to throw several of the control stations to the desired positions after which the control automatically completes the cycle of opening or closing the valves, as desired, and then returns the control stations to neutral position. The lights indicate when the valve operating unit starts up and also shows when the operation is completed.

A variable cycle furnace top controller for use in connection with the McKee revolving top has been developed.

In the past it has been the practice to revolve the furnace top with the load deposited from the skip pocket before dumping into the big bell in accordance with a fixed cycle. Most commonly six loads have been dumped in succession at six different dumping points. With the newly developed controller, it is possible to vary the number of loads dumped into the different positions from four to nine. This change in cycle is being obtained by a manually operated position switch on the panel. This type of control insures better distribution of

the material in the furnace as it is possible to vary the cycle depending upon the grade of material.

Semi-automatic controllers for magnetic clutches have been developed to reduce the time characteristic of the clutch and provide for a quicker application and less lining wear. The controller makes possible the use of a partial voltage coil in the clutch, which provides excess torque at the beginning, and assures quick building of the torque. After the clutch is engaged, the current and torque is reduced.

Recently there has been completed the design of a line of auxiliary steel mill controllers using a new inductive time limit accelerating relay. The relay is for general use where definite time acceleration is desired. The design of the relay is such that it is not necessary to include an air gap in the magnetic circuit, which has the advantage that a relatively long time element can be obtained and stronger contact pressure can be used, thus minimizing trouble from vibration, corrosion, dirt, etc.

In order to provide a better means for controlling the plugging of mill motors, this company has developed a new plugging relay. The function of this relay is to prevent the plugging contactor from closing to short circuit the plugging resistor before the motor armature is at rest. The relay consists essentially of a moving coil in a non-magnetic yoke, and so arranged that its direction of travel depends only on the direction of counter e.m.f. of the motor armature or on the armature (R1) drop. The relay can be readily connected into the control circuit of the reversing and plugging controller, so that the plugging contactor will close immediately when starting the motor from rest, but cannot close when plugging the motor until the armature has come approximately to rest.

During the past year there has been placed in operation in Chicago a hot strip reel motor drive with special control which keeps the reel speed synchronized to the speed of the hot mill finishing stand, and at the same time causes the reel motor to automatically slow down as the strip roll builds up on the reel.

The use of such a reel drive will, in many cases, mean that the hot bed can be made much smaller with a resultant savings in investment cost on the mill. This drive also removes the limitations of the length of strip that may be rolled, as far as reel drive is concerned.

A new method of obtaining definite time limit acceleration with magnetic contactors and without the use of the usual extra relay or transformer has been placed on the market by one of the most recent entrants in the electric control field. In brief, a magnetic contactor which is its own relay has been placed on the market. The combination of the accelerating contactor with the reversing contactor makes possible a very simple reversing magnetic control board.

It is very interesting to note the number of new applications that have been found for this old principle. By the use of Ward-Leonard combined with field weakening on the motor, speed ranges as great as 20 or even 30 to 1 can be secured. With such a Ward-Leonard system, the control is very inexpensive and goes quite a long way toward paying for the extra expense of the individual generator. This type of drive has been used on galvanizing take-up frames in several instances.

Nickel Alloy Cast Grid Resistors were announced as standard equipment by one of the manufacturers of Electric Control for all apparatus formerly using Cast Iron Grids. Nickel Allow Resistors are being supplied under a one-year guarantee against breakage in service or shipment.

A large amount of development was undertaken on self-contained oil-immersed automatic starters for Synchronous Motors. Starters of full voltage and reduced voltage types being produced.

Automatic AC starters to give quick stop by plugging or by dynamic braking, particularly suitable for rubber mill rolls, etc., were developed.

Magnets

The use of water transportation for iron and steel products developed tremendously during this year resulting in the establishment of public docks equipped with cranes and magnets in all our large cities and in practically all of the steel plants located along navigable waters. In one or two cases steel companies have equipped ore bridge hoists with a pair of 55" diameter magnets so as to increase the lift at each hoist which would justify the operation of so large a mechanism.

The use of magnets for handling hot iron or steel has expanded considerably during the year and now includes quite a few installations using rectangular magnets for handling hot strip steel in rolls either sideways or on end. The process usually saves 2 or 3 men on each turn, saves a great deal of other space because the steel can be kept in regular piles going up as high as the crane will permit and increases the production of the mill by preventing blockades.

Magnetic Separation is broadening to include soap manufacturers, lead smelters, copper producers and more recently coal mines. One large company bring their coal out of the mine on a belt 60" wide and protected with a 65" magnet hung in front of the head pulley and we understand saves enough usable iron and steel pieces such as chains, nuts, spikes, chisels and so on to pay the cost of the magnet each year and in addition saves the crushing machinery of their customer.

Oil Switching Equipment

Interstate Iron and Steel Company have installed recently armorclad switchgear for control of incoming lines, one 6000 HP motor and three KW motor generator sets.

The equipment consists of three 1600 Amp., 60 cycle, 7500 volt units and one skeleton unit for a future addition of another unit. Also nine 600 Amp., 60 cycle, 7500 volt units.

The complete armorclad units including bus, disconnects, instrument transformers, etc., were shipped in five groups. The installation consisted only of leveling and bolting down units, making cable and control connection to the units and assembling four band joints for the bus connection.

A new motor operated closing mechanism has been developed for use with oil circuit breakers.

It is a very compact, strongly constructed operating mechanism especially designed for application to moderate capacity oil circuit breakers.

It consists essentially of a combination of springs, mechanism and a motor so arranged as to permit the storing of energy in the springs by the motor, this energy to be released suddenly against the mechanism for a closure at will or automatically.

The mechanism is so arranged that the closing spring is always kept under tension ready for closure. It is not necessary for the motor to set the spring before closing. The motor sets the spring after closing operation—the spring being then held ready for another closure.

The speed of closure is very high. Less than one-quarter second is required from the time the release coil is energized to the closed position of the oil circuit breaker. It is therefore suitable for operation of oil circuit breakers synchronizing purposes and for automatic change-over switching.

After the circuit breaker has been closed, it requires from five to ten seconds for the motor to store energy in the spring for the next operation, depending on the size and type of the oil circuit breaker.

By means of an external timing relay, the motor mechanism and oil circuit breaker may be arranged for automatic reclosing duty. The number of closures and time intervals between closures will depend upon the timing relay employed.

MISCELLANEOUS

Silent Gear Material

A new type of Silent Gear Material has been developed known as Graphite Asbestos Gear Material. As its name indicates, this materials is made from Asbestos Fibre, Graphite, Brass Wire, and a special binding compound densely compacted together by vulcanizing under enormous pressure into homogeneous Sheets. These Sheets are then cemented together to form the Gear Blank stock.

This material is impervious to the action of oil or water and when necessary can be run in either an oil or water bath. Lubrication is not required when the materials run dry. The material is furnished in either the form of blanks or as the finished gear or pinion.

Superex Insulation

There has been developed a type of insulation known as "Superex." This material has a low thermal conductivity and a high heat resistance factor. It is exceptionally well adapted for temperature conditions ranging up to 1500 degrees Fahrenheit, and although it weighs only twenty-four pounds per cubic foot, has very satisfactory mechanical strength.

This material is being extensively used in connection with the insulation of Hot Blast Stoves, Regenerator Chambers, Heating Furnaces, etc., and is particularly adapted to the insulation of various types of electrically heated furnaces.

Lubrication

One of the nationally known manufacturers of lubrication equipment have placed on the market a Pneumatic Safety Lubricator which offers no added feature in the distribution of grease through the header lines. It does, however, offer a new principal in energy application by a compressed air feature instead of a manually operated prime mover.

The lubricator consists of a conical base grease tank and a suitably designed air compressor direct connected to a motor. There is an automatic control switch which permits of an elevation of pressure to that degree (210 pounds approximately) which is regarded as the peak load of pressure necessary and requisite. When the pressure is depressed to approximately 170 to 180 pounds, the motor is "cut in" and when the elevation of 210 pounds pressure is reached the motor cuts out. This maintains a reasonable and sufficient or proper balance of pressure between the mean and the high elevations. The distribution of grease at terminal ends should be made at the high elevation of pressure. This will permit of a reasonable and satisfactory flow of grease at the lower elevations.

CONCLUSION

The information given in this report covers only a portion of the development which has taken place during the past year. To cover the entire field would be too great an undertaking for a report of this nature.

Never did we realize as we have this year what a small portion of the entire field of development we are in a position to discuss. This is accounted for by the fact that during this year the members of the A. I. & S. E. E. were given an opportunity to visit the research laboratories maintained by Electrical Manufacturing Companies and were shown the vast amount of research work which is being done. What we saw convinced those who were fortunate enough to be able to take advantage of the opportunities that this is the reason why such progress is being made in the Electrical Industry. The unprecedented American prosperity is due in a large measure to the use of electricity which can be so readily generated and is capable of innumerable applications. This universal use of electricity is a direct result of the Research and Development Work.

To all those who have contributed to this report we wish to express our sincere appreciation and I am sure all connected with the steel industry will agree that this industry as a whole has been greatly benefited by development work carried on by the manufacturers of Electrical Equipment.

IRON AND STEEL EXPOSITION

June 25-26-27-28, 1928

HOTEL STEVENS, CHICAGO, ILL.

EVERYBODY WELCOME

*Selection of Motors for Main Drives of Merchant, Bar and Rod Mills**

By C. B. HOUSTON†

IT is the writer's intention to give in this paper a description of a sufficient number and types of mills and their drives so that the reader may gain some knowledge of the applications which have been made of electric motors to merchant bar and rod mills, and at the same time to show the kind of mill and the particular layout of the mill may materially effect the choice of motor, as to type, capacity, speed and method of control. The subject covers an exceedingly broad range and it will not be possible to describe all forms of these mills in all stages of their development. However, a little bit of the early history and important stages of development are given as a matter of interest to show, if possible, the reasons for present day practices.

Merchant bars may be defined as finihsed product in the form of rounds, squares, flats and small shapes. This naturally takes in a very broad range of product. To shapes alone may be added small size angles T's, channels and any special section that the trade may demand.

Rod is more easily defined as being a round bar which is rolled exclusively for drawing into wire. No. 5 rod (0.207 in. diameter) is the usual size rolled although some recent mills have been built for rolling size No. 7 as regular product.

The importance of these two branches of steel rolling to the industry are evidenced by the large number of such mills in use in this country. We need only refer to our published list of main motor drives and observe the large number of motors applied to this work as compared with those in other types of mills. For instance, under the classification of rod mills we have, up to January 1, 1928, 59 main motors 300 h.p. and above, totaling 76,010 h.p. For merchant mills we have 277 motors, totaling 234,825 h.p. These figures alone mean little except in a comparative way. The combined motor drives on rod and merchant mills represent 22.4% in number, and 16% in horsepower rating of the total main motor drives for all mills.

Also, the magnitude of these branches of steel rolling is told by the tabulation of the tonnages rolled in the United States during a period of twenty years (see Table I). It will be observed that the tonnage of wire rod alone averages close to 10% of the total steel rolled; while merchant bar (including concrete reinforcing bar) ranges from 15 to 20%. These figures are taken from data compiled by the American Iron and Steel Institute and include outputs for twenty years, up to and including 1926.

Both rod and merchant bar are rolled from billets usually varying in size from 1¾ in. square up to 4" square. The billets are always reheated prior to rolling.

*To be presented at A. I. & S. E. E. Annual Convention, June 25-28, 1928.

†Industrial Engineering Dept., General Electric Company, Schenectady, N. Y.

ROD MILLS

Rod and some of the simple shapes of merchant bar were first produced by rolling in 1783 by a mill built by Henry Cort, in England. He patented the grooved roll which made possible rolling this small material. Heretofore all rolling was confined to plates from which strips were slit off to obtain material in small sections. Cort's mill consisted of two rolls in one stand operated by two men, the roller who inserted the bar into the rolls, and the "catcher" who caught the bar as it came out of the mill, and who passed it back over the top roll.

It was not until 1857 that the first three-high mill was devised and tried after considerable persuasion on the part of its inventor, John Fritz. This occurred at the Cambria Iron Works, Cambria, Pa. The development of the three-high mill meant a great deal, especially to the production of rods, because the steel could be rolled in each direction through the mill and thus saved a great deal of time as well as permitted rolling to much smaller gauge. It is at this stage that we see the art of rolling rods advance over the rolling of any other class of product, and rightly so because of the demand for wire established by the invention of the telegraph.

TABLE I—Annual production of wire rod, merchant bar, concrete bar, and total gross tonnage of steel rolled in United States.

Year	Wire Rod	Merchant Bar	Concrete Bar	Total all Steel Rolled
1907	2,017,583	3,970,988		19,864,822
1908	1,816,949	1,986,638		11,828,193
1909	2,335,685	3,263,531	159,352	19,644,690
1910	2,241,830	3,785,731	241,109	21,621,279
1911	2,450,453	3,047,362	258,741	19,039,171
1912	2,653,553	3,697,114	274,332	24,656,841
1913	2,464,807	3,957,609	319,670	24,791,243
1914	2,431,714	2,523,631	288,471	18,370,196
1915	3,095,907	4,131,242	353,408	24,392,924
1916	3,518,743	6,230,302	461,400	32,380,389
1917	3,137,138	6,209,957	471,184	33,067,700
1918	2,562,390	6,242,749	344,620	31,155,754
1919	2,538,476	4,391,624	419,021	25,101,544
1920	3,136,907	6,130,240	572,445	32,347,863
1921	1,564,330	1,565,754	227,228	14,774,006
1922	2,654,741	3,978,658	575,816	26,452,004
1923	3,075,892	5,552,796	680,867	33,277,076
1924	2,522,545	4,280,921	656,122	28,086,435
1925	2,844,656	5,659,315	819,587	33,386,960
1926	2,722,032	5,473,836	815,829	35,495,892

Belgian Mills

With the advent of the three-high mill the "catcher" soon found, when rolling small rounds, that the bar while hot was flexible enough to be bent around and started back into the rolls again before the first pass was completed. This looping was done by catching the end of the bar with a pair of tongs as it came through the mill, and swinging it around to enter it into another set of grooves

in the rolls. It then was up to the roller to do the same as the "catcher" but he, already being busy feeding the bar on the first pass, required a helper. Then, in order to make room for the helper to work, a second set of rolls was added and direct connected to the first set. This formed what is called a train of rolls. These trains soon grew to five or six stands, set up end to end and direct connected to each other.

It was soon found that the speed of the rolls necessary for handling the roughing or break-down passes was curtailing the output of the mill. The roughing stand was accordingly removed from the rest of the train and driven by means of rope drive from the other stands. This permitted running the finishing mill at a faster speed than the rougher. The latter was still left two-high and the bars

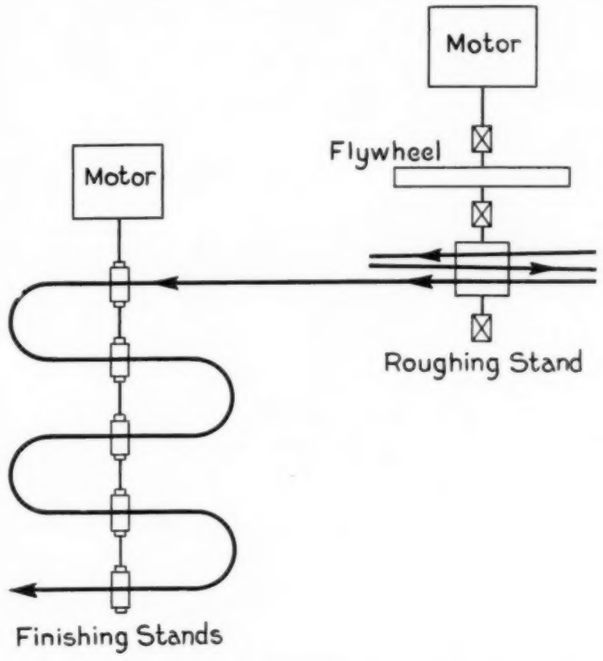


FIG. 1—Layout of simple Belgian mill, with separate motor on roughing and finishing trains. The finishing mill is frequently termed a guide mill.

passed back and forth for the first few break-down passes. Thus, we have the early development of the Belgian Mill, as shown in the layout Fig. 1. A separate motor is used on each mill, and because of the short duration of the passes in the roughing stand a flywheel may be added to advantage. There are a great many such mills still in operation today but they are limited to the production of special alloys or tool steel for which the demand in tonnage is low. Ordinarily each motor is a constant speed wound rotor type induction motor, although there have been several applications of two-speed and multi-speed motors. The latter forms have the advantage of giving a selection of speeds for rolling large or small sections of product.

Continuous Rod Mills

It was in 1862 that George Bedson of England invented and built the first continuous mill. He used sixteen stands, alternating horizontal and vertical rolls, which were all geared to a common line shaft and driven by one steam engine. The gear ratios were so worked out that each roll would rotate at a relatively faster speed than the preceding one by an amount dependent upon the draft to be taken. It is interesting to note that this first continuous mill was in continuous service at the Bradford Iron Works, Manchester, England until 1884. With this new form of continuous rolling of

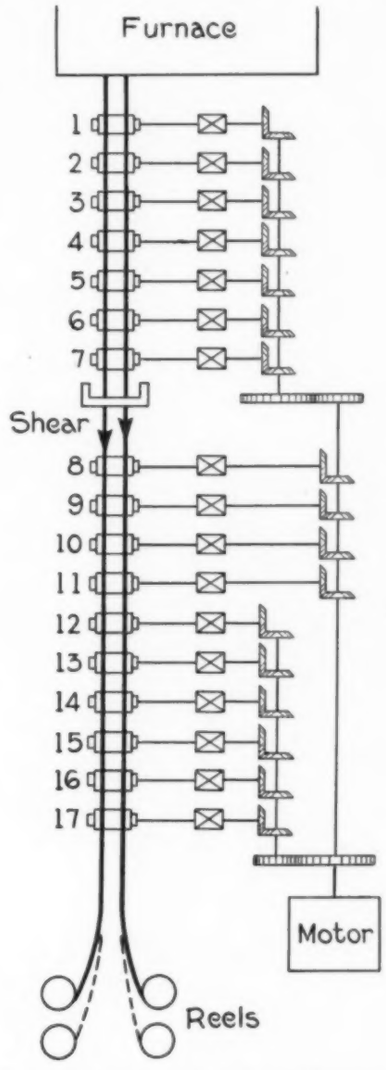


FIG. 2—Layout of 10" continuous rod mill, Sparrows Point, Maryland, Plant, Bethlehem Steel Co.

rod the delivery speed of the metal soon became limited entirely by the facilities for handling it at the reel.

It was at this stage that development began in this country. Instead of alternating horizontal and vertical rolls to get the reduction first through one axis and then through the other, all rolls were made horizontal and by means of guides leading from one stand to the other the metal was given a 90 deg. turn so as to bring the reduction in the right axis for each succeeding pass. These guides acted the same as the rifling in the barrel of a gun which

turns the bullet as it progresses forward. At the same time improvements were made in the reel which permitted speeding up the whole mill. Having no vertical rolls to interfere, there then was nothing to prevent running through two bars at a time. This was done by having a second set of grooves in the rolls, a second set of guides and additional reels. Thus we have the development of the continuous rod mill as we know it today.

There were, of course, many difficulties encountered—the main one to get the rod to successfully pass through the guides. Failure in this respect of course means a cobble and it is here that the flying shear aided to a great extent in the high speed rolling of rods. Having the shear placed usually just following the roughing stands it can be used, in case of trouble in any of the finishing stands, to cut the bar and thus reduce the amount of metal which is fed into the place at fault.

Fig. 2 is a layout of the 10" rod mill at the Sparrows Point Plant of the Bethlehem Steel Company, which is of the continuous type just described. This mill consists of seven roughing stands and ten finishing stands all set up directly in line. No. 5 rod is rolled almost exclusively and this is done two strands at a time, reducing from billets 1¾"

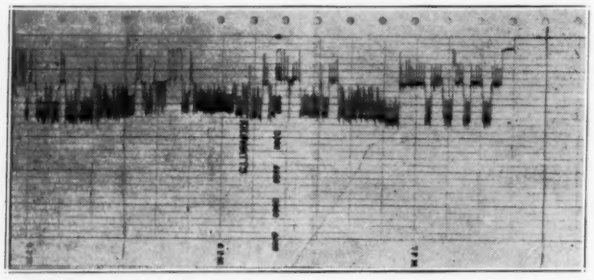


FIG. 3—Graphic wattmeter chart of input to 4000 h.p. motor on rod mill shown in Fig. 2.

x1¾". The capacity of this mill is approximately 120,000 tons yearly. Material is delivered at a rate of about 3300 feet per minute and coiled into bundles weighing approximately 300 pounds.

All stands are geared to one main motor which is wound rotor type induction motor rated 4000 h.p. (50 deg. C.)-375 r.p.m. synchronous speed-6600 volts-3 phase-25 cycles, and was supplied by the General Electric Company.

Fig. 3 is a graphic wattmeter chart of input to the induction motor on this mill. Except for the variation caused by either one or two bars being in the mill, the load is very constant. This is, in reality, an ideal application for a synchronous motor, and probably if the drive was being supplied today it would be this type.

Leading up to the development of the straight away continuous rod mill there have been several versions of semi-continuous mills, most notable of which is the form shown by Fig. 4. This layout represents the 10" mill of Keystone Steel and Wire Company, Peoria, Ill., and also the rod mill at the Wickwire Spencer Steel Company, Buffalo, N. Y. The roughing mill of six stands and the first intermediate of four stands are driven by one motor. The second intermediate of two stands, and the finishing mill of four stands, are driven by a second motor. Each drive is an adjustable speed induction motor with Scherbius type speed regulating control. Adjustable speed is one of the essential requirements for these drives although each motor may operate 90% of the time at one setting. Speed adjustment does permit controlling the loop between the two sections of intermediate stands.

Either of these two mills are capable of producing about the same tonnage as the Sparrows Point mill, previously described, when operating of course at their maximum speeds. Likewise, the load conditions are very constant as will be seen from the graphic wattmeter charts, Fig. 5, taken on the Key-

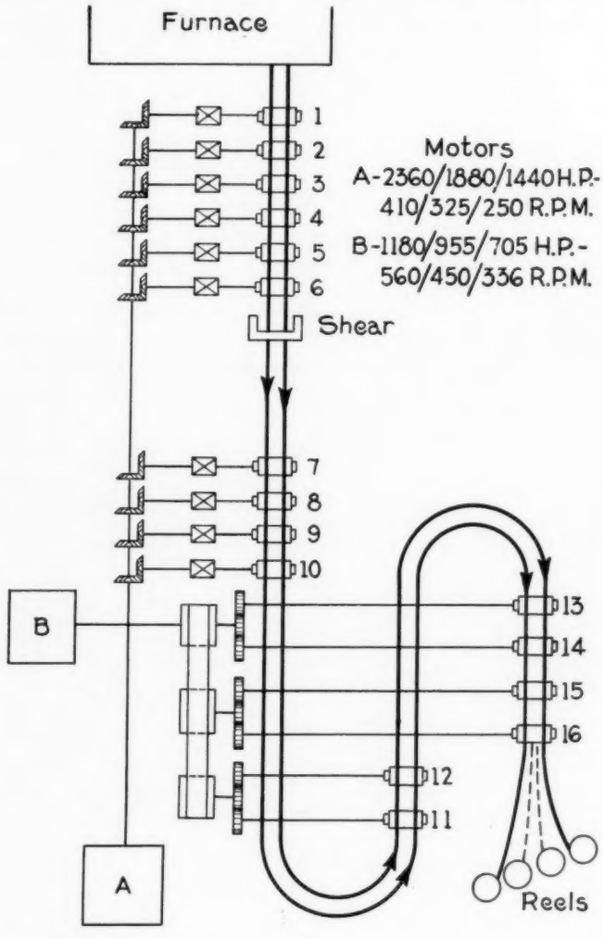


FIG. 4—Layout of 10" rod mill, Keystone Steel and Wire Co., Peoria, Ill.

stone Steel and Wire Company mill when rolling No. 5 rod.

In later developments of these mills the second intermediate stands have been placed directly in line with the first intermediate and roughing stands and are driven by a separate motor. The finishing end is divided into two mills of four stands each, and each mill is driven by a separate motor. These two finishing mills are off set, one to the right and one to the left of the rest of the rolls. Thus, the metal passes double strand through the rougher and intermediate mills, after which the two strands separate, one rod going to the finishing mill on the

right and the other to the finishing mill on the left. This arrangement of splitting the finishing makes the mill somewhat safer to operate and smaller rod and better quality can be rolled than on the former types where the double strand is carried all the way through.

The first installation, in this country of a mill of the kind just described, was the 10" rod mill at the Portsmouth, Ohio, plant of the Wheeling Steel Corporation. The motor drive which was supplied by the General Electric Company is direct current throughout consisting of one 1435/2870 h.p. 200/400 r.p.m. motor driving seven 12" and four 10" roughing stands; one 363/800 h.p. 320/706 r.p.m. motor driving the two intermediate stands; and two more duplicate 800 h.p. motors driving each of the two finishing stands. All motors are 600 volts direct current, power being supplied by a synchronous motor generator. The use of direct current gives

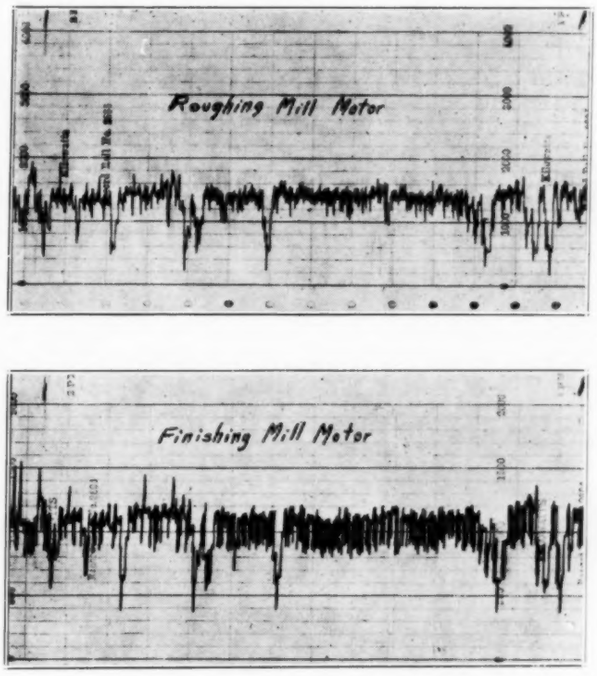


FIG. 5—Graphic wattmeter charts of kilowatt input to motors driving the rod mill of Fig. 4.

great flexibility in the choice of speeds for different products and control of the loops between the intermediate and finishing stands.

The most recent mill of this same type is the new 10" rod mill at the Worcester, Mass., plant of the American Steel and Wire Company. This is not only the highest speed mill in the country (No. 7 gauge wire rod being finished at a speed of 4000 feet per minute), but is also the first mill to produce single bundles weighing as much as 400 pound. The tonnage is approximately 100,000 tons yearly.

The motors for this mill were supplied by the Westinghouse Electric Manufacturing Company and consist of one 3000 h.p.-180/370 r.p.m. motor driving the roughing and intermediate stands, and two duplicate 800 h.p.-535/750 r.p.m. motor driving each of the two finishing stands. All motors are 600 volts and power is supplied by synchronous motor generators. Direct current again enables easy control of the loop between the rougher and finisher stands and permits running the mill at different speeds to best suit the product being rolled.

Garrett Rod Mill

Paralleling the early growth of the continuous rod mill there was carried on an entirely different line of development of the semi-continuous type which is known as the Garrett mill, named after William Garrett, the inventor.

The first improvement which Garrett made was to combine a continuous mill as a rougher with the looping trains of the finishing mill. Billets as large as 4"x4" were used instead of the smaller sizes thus far tried. This size was decided upon because it was thought they could be successfully produced in the blooming mill and thus save work of further reduction through a separate billet mill.

As a second step, improvements were made upon the finishing train of the Belgian mill. Instead of driving all the finishing rolls at the same speed Garrett regrouped the stands driving each stand or each two stands at a different speed, gradually step-

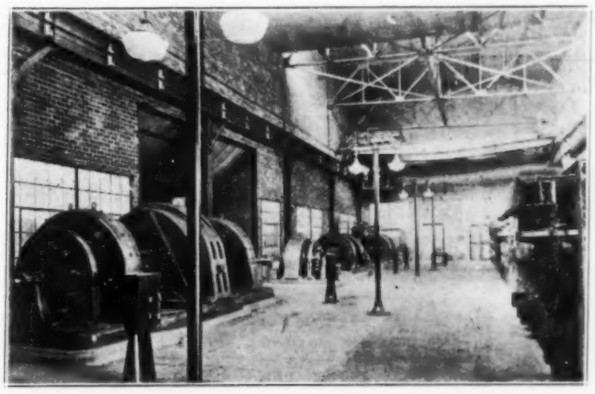


FIG. 6—Motor room of 10" rod mill, Wheeling Steel Corp., Portsmouth, O. The 3000 kw. motor generator in the foreground served 600 volt power to the (1) 2870 h.p. and (3) 800 h.p. motors driving the mill.

ping up toward the last or finishing roll. This meant that the loops could be held more nearly constant rather than allowing them to grow from one pass to the other. Not only was time saved in the rolling of the bar but also the bar could be gotten through the mill at a much higher temperature, both of which add greatly to the economy of the operation of the mill.

Also as further improvement upon the finishing end of these mills was the development of the repeater. This is a metal trough bent in a semicircle in which the bar is carried from the rolls of one pass around to the rolls of the next pass. The top of the trough is open and side walls are sufficiently low so that the bar easily climbs out of the groove when an excess of material is being fed from the delivering roll. These repeaters, which are still used today, have been found applicable only on passes where a square section of rod is being delivered. The oval section still must be handled by hand on any looping pass. The delivery speed is, therefore, limited by the ability of the men to

handle the loop preceding the last stand. The maximum speed which can be successfully handled is approximately 1350 feet per minute. Strange to say, it is not the catching of the metal, which of course requires great skill, that limits delivery speed on these looping mills, but the mechanical shock which is transmitted through the tongs as the piece enters between the rolls. This means, when allowing for the reduction on the last pass, the speed of delivery is limited to approximately 1600 feet per minute.

The Garrett rod mill has been very popular as evidenced by the very large number of them in use, both steam and electric driven. To make up for slow delivery as compared to that of a continuous

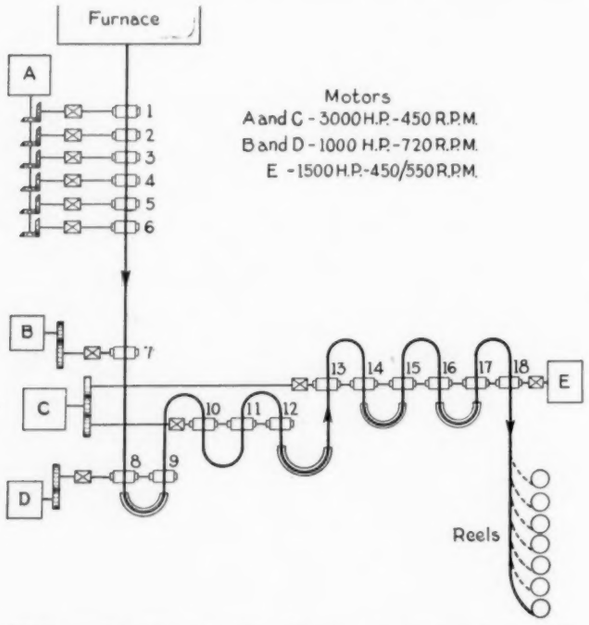


FIG. 7—Layout of 10" Garrett type looping mill, Colorado Fuel and Iron Co., Pueblo, Colorado.

mill, more than one bar is finished at a time. The roughing stands are accordingly speeded up so that metal is fed through them to the first hand looping stand faster than the following stand will handle single stranded, which means that the head end of the second bar comes through this pass before the tail end of the first bar has passed through the following stand. The "catcher" simply starts the second bar through another set of grooves, making two bars in this one stand for a short time. The doubling up of the passes will, in this way, increase until at the last stand five or six strands may be finishing at one time.

There is provided in such cases one reel in addition to the number corresponding to the workable grooves in the rolls of the finishing stand. The repeaters are also provided with separate troughs for each set of grooves so that the mill may be kept "full", so to speak, for an indefinite period of time. In this way a tonnage can be rolled comparable with continuous mills. The yearly output of a mill with six reels is 120,000 tons.

There have been a great many variations in the grouping of the stands and the speeds of the various rolls on these Garrett rod mills, but the 10" mill of the Colorado Fuel and Iron Company, Pueblo, Colorado, is as good an example as can be chosen, which layout is shown in Fig. 7. No. 5 rod is rolled directly from 4"x4" billets. This mill was electrified in 1925, all motors being supplied by the General Electric Company. There are a total of eighteen stands which have been divided as follows: Roughing—stands 1 to 6 inclusive, 3000 h.p.-450 r.p.m. induction motor; stand 7, 1000 h.p.-720 r.p.m. induction motor; stands 8 and 9, 1000 h.p.-720 r.p.m. induction motor; stands 10 to 15 inclusive, 3000 h.p.-450 r.p.m. induction motor; stands 16, 17 and 18, 1500 h.p.-450/550 r.p.m. direct current motor. All induction motors are constant speed wound rotor type, 6600 volts, 3 phase, 60 cycles. The direct current motor is 600 volts, power being obtained from a synchronous converter, and adjustable speed 450 to 550 r.p.m. is obtained by field control on the motor itself.

MERCHANT MILLS

The development of the merchant mill has not been carried out on such a distinct line as the rod mill. This is due perhaps to the diversified line of product which falls under this classification. Wire rod can readily be rolled on any merchant mill equipped with a reel, but rod mills, as layed out and operated, are not adaptable for handling general merchant stock. For this reason merchant mills,

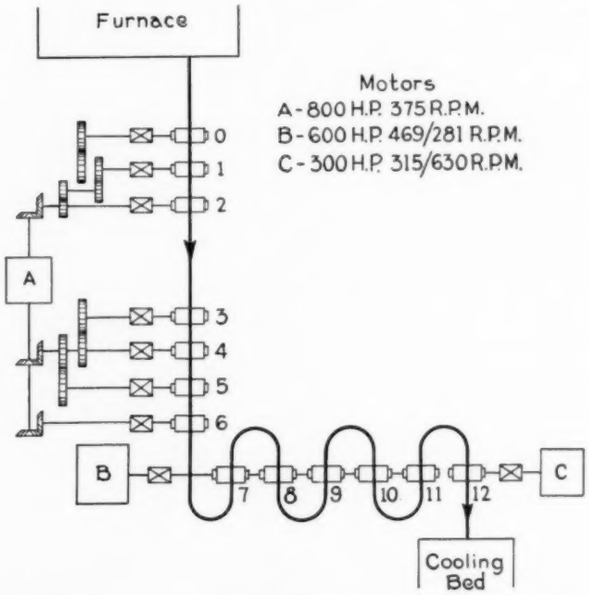


FIG. 8 Layout of 8" merchant mill, Donner Steel Co., Buffalo, N. Y.

as a whole, are more general in their nature. However, a classification which can be given and which includes all the present day developments is:

1. Semi-continuous looping.
2. Semi-continuous due staggered or cross-country.
3. Straight continuous.

All merchant mills are equipped with some form of a cooling bed onto which the material may be run from the finishing stand where it is allowed to cool before being cut into lengths for shipment.

For some of the smaller products reels are provided and the material is coiled just the same as wire rod.

Semi-Continuous Looping Mill

To this group belong probably 90% of the merchant mills in operation today. Many are quite ancient in their date of origin but are still giving service rolling alloys in limited quantities or special sections that may have their outlets within the same plant. These usually have some simple form of motor drive if electrified, and have little interest to us as an influencing factor for future applications.

The 8" mill of the Donner Steel Company, Buffalo, N. Y., is a very good example of a general purpose hand operated mill of the semi-continuous looping type for which the layout is shown in Fig. 8. The roughing end consists of seven 11" stands, geared to one 800 h.p.-375 r.p.m. constant speed wound rotor type 2200 volt-3 phase-25 cycle induction motor. The intermediate stands 7 to 11 inclusive, are driven by a 600 h.p.-469/375/281 r.p.m. adjustable speed wound rotor induction motor with double range Sherbius speed regulating equipment. The finishing stand No. 12 is driven by a 300 h.p.-315/630 r.p.m. adjustable speed 230 volt direct current motor. Adjustable features on each of the intermediate and the finishing stands provide flexibility in the choice of speed of these rolls to take care of a wide range of product. Speed control on the rougher is not so important because by starting with the same size billets 1¾"x1¾", the reduction through these passes remains about the same for all products rolled. Occasionally, however, one stand may be "dummied" so as to bring the section to the desired size and shape out of this end of the mill.

A representative illustration of an up-to-date semi-continuous looping mill is the 11" merchant mill of the Tennessee Coal, Iron and Railroad Company, Fairfield, Alabama. This is shown in the layout Fig. 9. The most special feature of this mill is its automatic operation throughout, repeaters being used on all looping stands.

The principal product is ⅜" to 1⅝" round, plain and deformed, squares, and small flats up to 3" wide, starting with billets of 4"x4" section. The rated tonnage for an average schedule is 10,000 tons per month. The electric drive is an Allis Chalmers Company installation throughout, being divided as follows: Six 16" continuous roughing stands driven by a 1500 h.p.-600 r.p.m. constant speed induction motor; four 12" continuous stands driven by a 1500 h.p.-890/540 r.p.m. adjustable speed induction motor with Kraemer speed control; three 12" intermediate looping stands driven by a 1250 h.p.-712/430 r.p.m. adjustable speed induction motor with Kraemer speed control; and one 11" finishing stand driven by a 500 h.p.-888/540 r.p.m. adjustable speed induction motor with the same type Kraemer speed control. All main motors are 6600 volts-3 phase-25 cycles. This is truly a high production mill and is rendered so not only on account of its automatic features for handling the metal but also because of the flexibility of the control of speed on all the drives.

A most interesting mill from the standpoint of flexibility of the electric drive is the new 10" semi-continuous looping mill of the Bourne Fuller Company, at their Union Works, Cleveland, Ohio.

This is comprised of four continuous roughing stands, all geared to one motor, originally 500 h.p.-267/800 r.p.m., but now being replaced by a 1000 h.p.-400/800 r.p.m. motor; four 12" continuous intermediate stands, set up in tandem, each driven by separate motor, three of which are 300 h.p.-267/800 r.p.m. and one 500 h.p.-267/800 r.p.m. motor; and four 10" finishing stands, each driven by a 500 h.p.-267/800 r.p.m. motor. The motors are 250 volt direct current and are supplied with power from two 1000 K.W. synchronous motor generators. All machines were supplied by the General Electric Company.

The unusual feature of this mill layout is the separate motor drive on each of the four intermediate stands which are not only arranged in

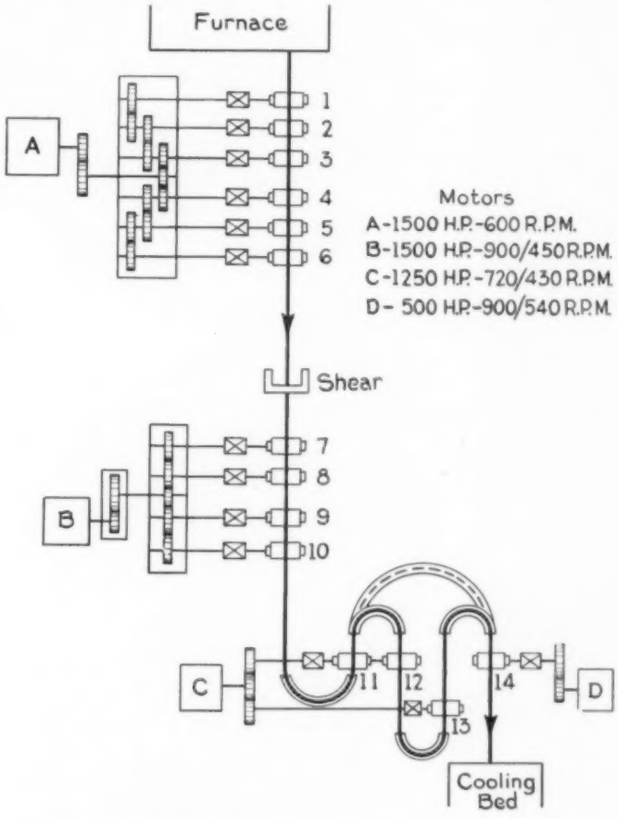


FIG. 9—Layout of 11" merchant mill, Tennessee Coal, Iron and Railroad Co., Fairfield, Alabama.

tandem but are located on close enough centers so that metal is in all rolls at the same time. An improvement in the quality of the material rolled is expected by having the flexibility of individual adjustable speed drive back to and including these four tandem stands 5, 6, 7 and 8. Special speed regulators have been provided with each motor, the purpose of which is to hold the speed of these four stands closely in step with each other. Thus, mechanical gearing which ordinarily would tie these stands together on one drive, or possibly tie them in common to the first four roughing stands, has been replaced by an electrical tie through these regulators. This arrangement affords independent selection of speed on the intermediate rolls and still maintains a close speed relationship between them.

The question always arises in such cases, however, as to whether the added refinement in speed regulators is really necessary. Until sufficient experience has been obtained by operating these types of drives, both with and without the regulating equipment, this question cannot be satisfactorily answered.

We find when looking back through the records of the Iron and Steel Engineer, Mr. A. F. Kenyon's very interesting description of the Westinghouse Electric Manufacturing Company's electrification of the 10" merchant mill of the Corrigan McKinney Steel Company, Cleveland, Ohio, which appears in the November number of 1927. Not only do we note the application of direct current motors throughout but also the special means by which the speed regulation of each motor is reduced to a minimum. The use of series exciters about which Mr. Kenyon tells us is one of several means of artifically overcoming speed regulation which is inherent with all direct current machines to a greater or lesser degree.

This mill we find has a roughing train driven by a 1000 h.p.-200/600 r.p.m. motor, an intermediate train driven by a 2000 h.p.-137/275 r.p.m. motor, and four finishing stands driven by a 1200 h.p.-300/550 r.p.m. motor. All motors operate from a constant potential 600 volt bus supplied with power by synchronous motor generators. The full amount of speed adjustment is obtained by shunt field control, and it is herein that the series exciter makes it possible to obtain a small degree of speed regulation throughout the full speed range. This is especially true in the case of the 1000 h.p. unit, which operates through a 3:1 range. This machine, by

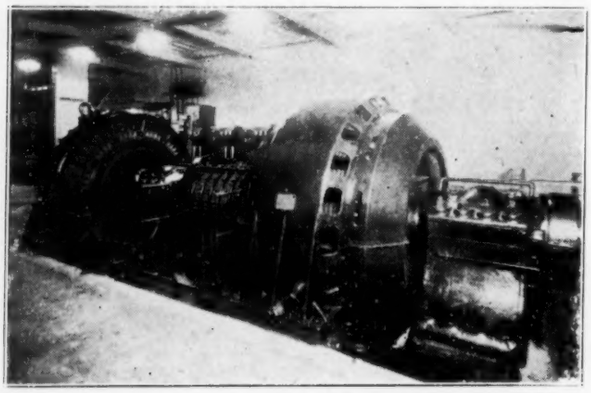


FIG. 10—4500 h.p.-500/300 r.p.m.-2200 volt-25 cycle induction motor Kraemer set driving the 14" merchant mill, Inland Steel Co., Indiana Harbor, Indiana.

the way, has been built with two 300 volt motors assembled on one shaft and connected in series for operation from the 600 volt bus.

Semi-Continuous Duo Staggered and Cross-country Mills

This is a type of mill which has come into prominence of late years. It is especially adaptable to the rolling of the larger sizes and special sections of merchant bar which cannot be looped between passes.

A typical installation of this sort is the 14" mill of the Inland Steel Company, Indiana Harbor, Ind., which is driven by a General Electric 4500 h.p.-500/300 r.p.m.-6600 volt-25 cycle adjustable speed induction motor with Kraemer speed regulating equipment consisting of a 1700 h.p.-300/500 r.p.m.-480 volt direct current motor direct connected to the induction motor, and a 1350 K.W.-100 r.p.m.-480 volt synchronous converter which converts alternating current slip energy of the induction motor into direct current for the d.c. motor unit. On account of the main induction motor having to carry the losses of the other machine, it is rated in electrical output 4750/2850 h.p. at 490/350 r.p.m. The unit delivers, however, constant mechanical output 4500 h.p. throughout its full speed range of 500 r.p.m.

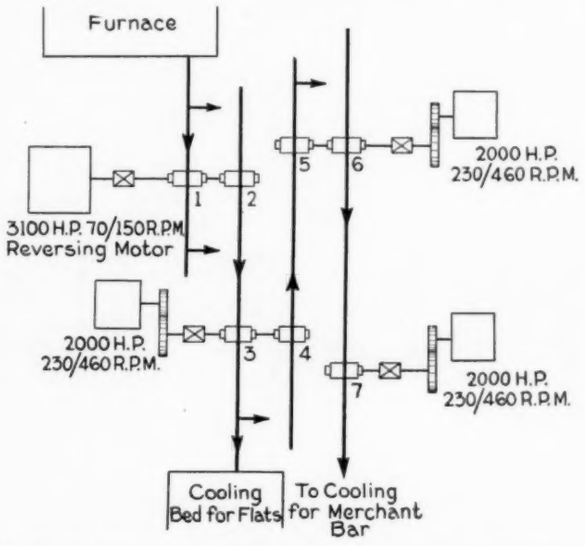


FIG. 11—Plan of 24"cross-country merchant mill, Wisconsin Steel Co., South Chicago, Ill.

(synchronous) down to 300 r.p.m. The maximum speed regulating duty is approximately 480 r.p.m. (full load) which corresponds to 1 cycle on the synchronous converter. When running non-regulating the full load speed is approximately 490 r.p.m. The control of this equipment is arranged so that the speed of the motor may be adjusted from a position out in the mill, but the starting is taken care of entirely through the control of the master switch located in the motor room.

All ten stands are geared to this one driving unit. The first six stands of 18" rolls are set up in tandem as a continuous mill. The remaining four stands of the 14" rolls are set up in two lines close together, but staggered one with the other. Metal when passing out of stand 6 runs onto a "skew-Y" table which not only carries the material longitudinally away from the last stand, but also transversely to line it up in front of the rolls of stand 7. The tables are then reversed to feed the material into stand 7. In like manner the bar is transferred to each of the succeeding stands, each time its direction of travel down the mill being reversed until finally delivered onto the cooling bed out of stand No. 11. If so desired a switch may be so placed as to transfer the bar from stand 7 to stand 10, and thus eliminate two of the passes. Throughout the whole operation the handling of the bar is entirely automatic except to give it a quarter turn before

entering some of the latter passes. This is done by turning the piece by hand with tongs or special "pike pole." The table rolls are controlled from a central point at one side of the building from where the whole mill is in view. An output of approximately 15,000 tons per month can be obtained even when rolling an average number of schedules which may vary from 7/8" to 3" diameter rounds, equivalent areas in squares, flats and various shapes.

There will be, of course, an over-lapping of the passes in order to keep the mill full, but over-lapping may at times have to be controlled in order to hold down the current peaks on the motor. The adjustable speed constant horsepower rating on the drive is required to obtain the desired torque for

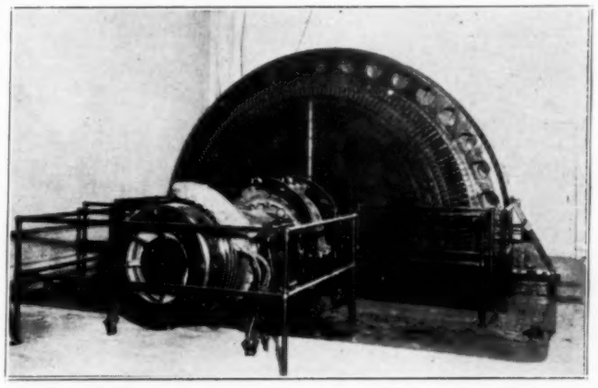


FIG. 12—5610/4500/3370 h.p.-150/125/93 r.p.m.-6600 volt-25 cycle induction motor with Scherbius speed control equipment used in driving the roughing stands of the 12" cross-country merchant mill, Corrigan-McKinney Steel Co., Cleveland, Ohio.

rolling the wide range of sections. The Kraemer type of speed control meets these conditions with the direct current motor unit direct connected to the main induction motor, see Fig. 10 which is a picture of the Inland installation.

The Ford Motor Company, Detroit, Mich., has a 14" merchant bar mill which is duplicate of the Inland Steel Company installation except for the electric drive and the plan of the mill which is just opposite handed from that of the latter. This Ford Company drive, by distinct preference of the user, is a direct current motor rated 4500 h.p.-67.5/110 r.p.m.-500 volts. Power is supplied by two 2000 K.W.-250 volt generators, connected in series. This mill has turned out some very favorable records of tonnages which can be obtained mainly because the schedules can be arranged within the Ford Company organization to roll for long periods on one section before shifting to something else. For this reason there is the least loss of time for changing rolls and otherwise adjusting the mill.

Other mills built along these same lines are the 13" and 14" mills of the Bethlehem Steel Company, Cambria plant, Johnstown, Pa. In either case the motor drive consist of two 1500 h.p. motors coupled together to form one unit driving the roughing and all but two of the finishing stands. The other two finishing stands are driven by a separate 1500 h.p. single motor. Provisions are accordingly made in arrangement of each mill, so that the two stands with single motor unit may be shut down and finishing done on the rest of the mill. All motors are direct current 250 volts and have a speed range of 150 to 300 r.p.m. Power is supplied to them by synchronous motor generators. All machines were manufactured by the Allis Chalmers Manufacturing Company.

A very interesting example of the cross-country type of construction is the 24" merchant mill of the Wisconsin Steel Company of the International Harvester Company, South Chicago, Ill. Material is rolled from reheated blooms to merchant bars 2½" up to 4½" maximum, beams up to 12", angles 3" up to 6", and a variety of flats 6" to 30" in width. It has, of course, a large range of tonnage output, up to 50 gross tons per hour in wide flats.

The plan of this 24" merchant mill is shown in Fig. 11, from which it will be noted that rolling is started with reversing passes through stands 1 and 2. When rolling heavy flats, finishing is done on stand 3, but for most merchant shapes all the passes are used. The term "cross-country" is applied to the description of this mill because of the lateral transfer of the metal when lining it up for some of the passes.

The electric drive which was furnished by the Westinghouse Electric Manufacturing Company consists of one 3100 h.p.-70/150 r.p.m. reversing motor driving the stands 1 and 2, three 2000 h.p.-230/460 r.p.m. motors, each driving respectively stands 3 and 4, stands 5 and 6, and the finishing stand 7. Power is supplied by a flywheel motor generator

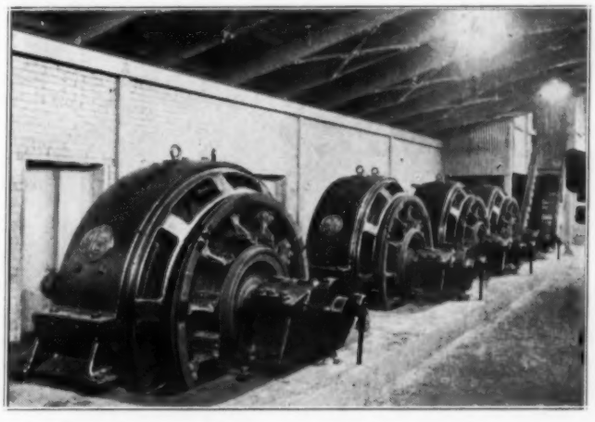


FIG. 13—(4) 800 h.p.-600 volt direct current motors driving the four finishing stands of the 12" merchant mill, Corrigan-McKinney Steel Co., Cleveland, Ohio.

consisting of two 3000 KW. direct current generators and one 6500 h.p. induction motor.

The Corrigan McKinney Steel Company have a semi-continuous cross-country type of mill in their 12" merchant mill, for which the electric drive has been divided among five motors. One is a 5610/4500/3370 h.p.-156/125/93.6 r.p.m. induction motor with double range Scherbius speed regulating control driving the roughing and intermediate stands. The other four motors driving the finishing stands are direct current 800 h.p., three of which have speed ranges 200/415 r.p.m. and one 240/480 r.p.m. Power for these four motors is supplied by one of the Westinghouse motor generators to which Mr. Kenyon in his description of the 10" merchant mill.

Continuous Merchant Mills

The development of merchant mills in general has been confined to the semi-continuous type of the forms previously described rather than to the straight continuous type. The reason for this is that merchant mills must cover a wide range of sizes and sections for which the usual continuous mill with fixed speed relationship between stands is not capable of handling. Therefore, a continuous merchant mill layout by necessity calls for individual adjustable speed drive on each stand, or at least on all except a few of the roughing or breakdown passes. Such an arrangement is, of course, expensive and in most cases the quantity of production has not justified the initial cost of either mill or drive.

The Jones and Laughlin Steel Corporation was the first to consider such a layout for the rolling of general merchant stock when the 14" mill was built at the Aliquippa Plant, Woodlawn, Pa. This mill which consists of nine horizontal and three vertical stands all set up in continuous line has an individual motor on each set of rolls except the first three, which are grouped together on one drive.

FIG. 14—Motor room of 14" merchant mill, Jones & Laughlin Steel Corp., Aliquippa Works, Woodlawn, Pa.

All motors are direct current, 600 volts, and instead of operating from a common bus, separate generators are used for each motor or pair of motors on adjacent stands, see Fig. 15. In this way speed adjustment by voltage control may be used to increase the range of individual or groups of stands beyond that obtainable by field control alone.

Two other such mills have just recently been placed in operation at the Illinois Steel Company, Gary, Ind. These are the 9" merchant mills No. 1, and the 10" merchant mill No. 4. A very complete description, including a layout of the 10" mill, was given in the October 29, 1927 issue of the Electrical World, of which some of the details are worthy of our consideration here. All stands are in direct line, see Fig. 16. Stand No. 1, which is driven by a 200 h.p.-240/900 r.p.m. motor acts mainly as a scale cracker as little reduction is expected through it. Stands 2 to 6 inclusive, are an ordinary geared continuous mill driven by one 2000 h.p.-315/500 r.p.m. motor. Stands 7 and 9 are each driven by separate motors 700 h.p.-130/310 r.p.m. Between these two stands is a set of vertical rolls, stand 8, driven by a 500 h.p.-130/310 r.p.m. motor. Stands 11 and 13 are each driven by separate motors rated 700 h.p.-210/660 r.p.m. and two more vertical rolls, stands 10 and 12, are each driven by separate motors rated 500 h.p.-150/550 r.p.m. This makes a total of thirteen sets of rolls including both horizontal and vertical, requiring nine motors.

The vertical rolls, it will be observed, alternate the horizontal rolls at the finishing end of the mill. Unlike the vertical rolls or edgers on strip mills which are mainly used to keep the material from spreading in width, these vertical rolls are intended for a full amount of reduction in the pass. The ratings of the motors driving them are comparable to those on the horizontal rolls. Arranging the passes in this way saves turning the bar 90 deg. following each of the last stands and, consequently, eliminates turning guides, which for some sections

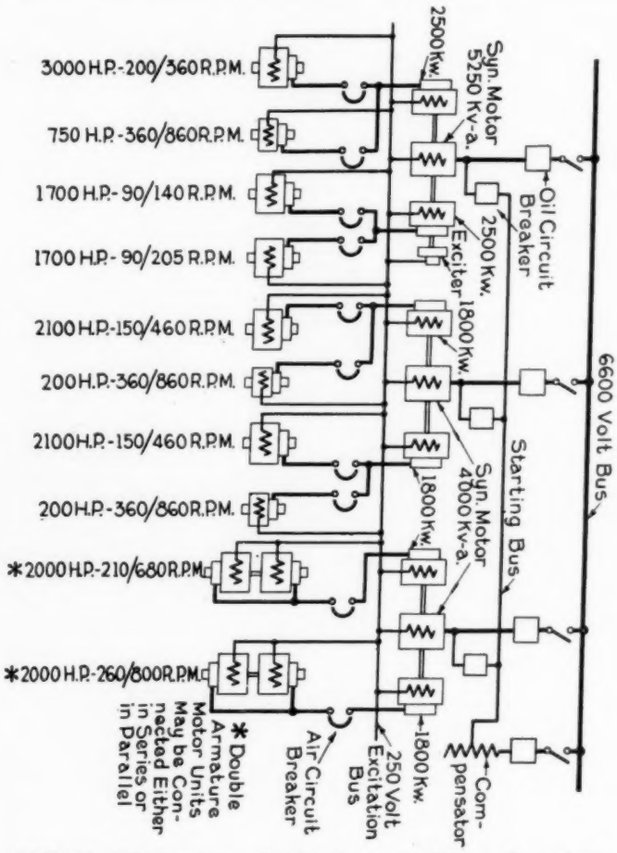


FIG. 15—Elementary electrical connections of motors and motor generators used in driving the 14" merchant mill, Jones & Laughlin Steel Corp., Woodlawn, Pa.

or shapes are either impossible or are very troublesome to handle in a straight away mill.

Special loopers consisting of horizontal semicircular tables are placed between the last five stands by means of which loops between these passes are taken care of when rolling rounds, squares or shapes. When flats are rolled separate channel troughs are shifted into position, in which the bottom is dropped down, after the metal has spanned the gap between rolls, and thus allows a loop to develop in the vertical plane. All of the motors are direct current 600 volts and supplied with power by a three unit 4000 KW. synchronous motor generator consisting of two 2000 KW. gen-

erators and one 5800 KVA. synchronous motor. The machines, both motors and generators, are separately excited from a 250 volt exciter which is direct connected to the motor generator.

Magnetic control for starting so large a number of motors would not only be expensive but would take up a great deal of installation space. Consequently, Ward Leonard control is used by which all motors are started simultaneously by building up the voltage on the generators. The generators, although operated in parallel, have their shunt fields connected in series so that their voltages may be built up together. Each motor, however, is controlled through its normal speed range by field control for which there are two field rheostats, one a coarse adjustment remotely controlled by pilot motor and the other a fine adjustment, operated by a hand lever. All circuit breakers are properly interlocked with each other, and with the main generator field rheostat as well as with counter EMF relays making it impossible to close any circuit with voltage already present either on machine or on the bus. The operation is made fool-proof in this respect. Even the starting of the synchronous motor on the motor generator is entirely automatic, it being only necessary for the operator to close the starting control switch.

There may at first be some objections to this method of control for the motors, mainly because of the necessity for shutting down the whole mill in case one machine trips off the line and must be restarted. This, in reality, is no handicap for if any one motor stops accidently while steel is coming through a cobble is formed, and before rolling can be resumed the tangled metal must be cleared away, in which case it is all right to stop the whole mill. In other words, the mill is inoperative with any one of the operating rolls shut down. Therefore, all rolls may as well be controlled as a group. Any stand which may be idle for a given schedule may, of course, be left so without interferring with the operation of the others.

There is one rather insignificant part of the electric drive which is really very important to the successful operation of the mill and that is the tachometer. The speeds of the various motors must be quite accurately set, otherwise, there may be disasterous results from stretching the bar or by forming too great a loop. Considerable attention has, therefore, been paid to the accuracy and the reliability of these tachometers. Geared to each main motor is a small direct current generator, across the armature of which is connected a voltmeter which is calibrated in r.p.m. of main motor, or speed of the rolls. The field of all of the tachometer generators are connected in series and excited from the 250 volt excitation bus. An ammeter and rheostat is provided so that the field current of the generators may be held constant, but after once set there is no reason for variations except as caused by temperature change in the fields. In any case all fields being connected in series any error is common to all and will affect the voltage of the generators or reading of speed on the tachometers a like amount in per cent. The relationship of the indicated speed remains the same and after all it is only relative speed, one roll to the others, that is important.

The 9" mill No. 1 at this same plant is similar to the 10" mill No. 4 except somewhat smaller. The electrical equipment for both was supplied by the General Electric Company.

TYPES OF DRIVES

From the foregoing descriptions of mills and their drives it will be noted that we have on both rod and merchant bar mills about every form of motor both alternating and direct current that exists. We find the wound rotor induction motor in single, two speed, and multi-speed designs. We also find the wound rotor induction motor with almost every conceivable form of speed adjusting equipment—Scherbius, Kraemer and frequency converter types; some of the latter being in operation at the International Nickel Company, Huntington, W. Va., and also at the Laclede Steel Company, St. Louis, Mo.

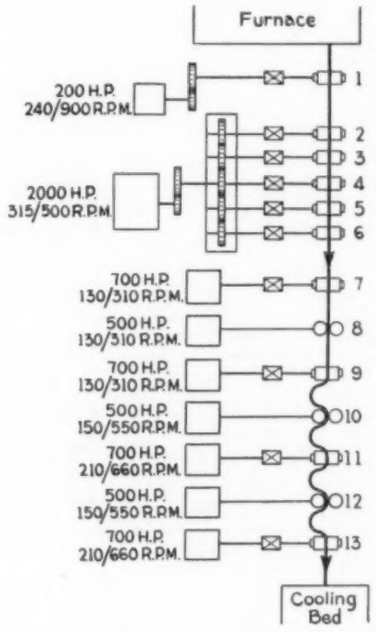


FIG. 16—Layout of 10" continuous merchant mill No. 4, Illinois Steel Co., Gary, Indiana.

We even find the alternating current adjustable speed brush shifting motors as applied to the 14" and 9" mills at the Halcomb Steel Company, Syracuse, N. Y.

Strange to say, it was not until early this year that the first synchronous motor has been sold for driving a mill of either type under consideration. This is an 800 h.p.-300 r.p.m.-.85 PF-2200 volts-60 cycle motor and is intended to drive four stands of the 10" merchant mill No. 2 at the Madison, Ill., Works of the Laclede Steel Company. There have been, however, several cases where the synchronous type of motor would have been applicable such as on the continuous rod mill at the Sparrows Point Plant of the Bethlehem Steel Company to which reference has previously been made. Also, the same statement may be made with reference to the continuous roughing trains of many of the semi-continuous looping mills; for example, the roughing stands of the 8" mill at the Donner Steel Company, which are at present driven by a constant speed in-

duction motor. We shall, no doubt, in the future see more of the synchronous motors used where constant speed sufficies.

We have, of course, the direct current motor with its adjustable speed characteristics used with and without speed regulating devices. In fact there is an ever growing tendency toward a greater use of direct current all because of the flexibility which its application makes available in operation of the mill. We find even on the continuous rod mills, where not many years ago alternating current motors with some form of speed adjustment were used, the application of direct current on all drives. This is true even at some additional expense of initial cost or lower efficiency, although with the improvements which have been made in recent years in the design and manufacture of direct current apparatus, there does not always exist a differential either in cost or efficiency in favor of alternating current machines. The simplicity and ease of control, however, is the influencing factor which makes direct current motors

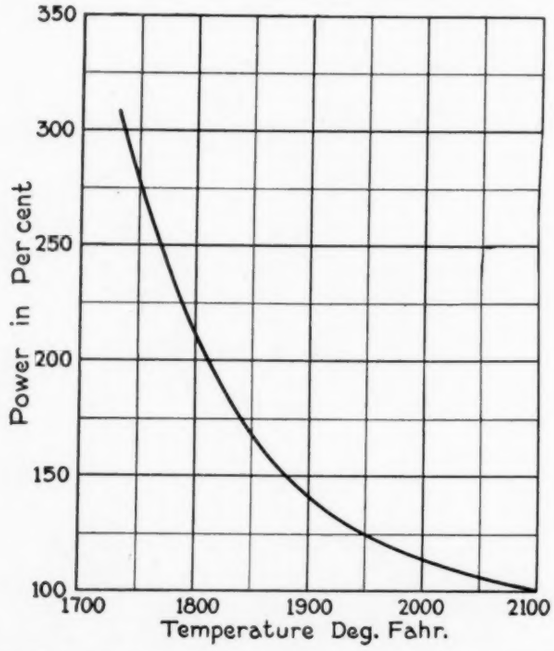


FIG. 17—Curve showing relationship between percentage power consumption and temperature of steel.

so suitable. For the continuous and for many of the semi-continuous mills only direct current can logically be considered, as for example the Illinois Steel Company 10″ mill No. 4, or even the Bourne Fuller Company's new 10″ merchant mill.

POWER REQUIREMENTS

The power required for rolling steel is usually expressed in terms of kilowatt-hours per gross ton of material rolled. There are many factors which influence the power requirements such as initial temperature of the steel, drop in temperature during rolling, arrangement of the rolls for open or closed passes effecting the friction, percentage time that mill runs light or is down for roll change, etc., and of course the percentage of elongation which is being made for one heat. Formulae have been developed and rules established by which an attempt is made to calculate power, but our most reliable information is taken directly from test or compilations of daily records of actual schedules of rolling.

The effect which temperature has on the power required for rolling steel is shown in a general way by the curve Fig. 17. It will be noted that the power just about doubles with a drop from 2100

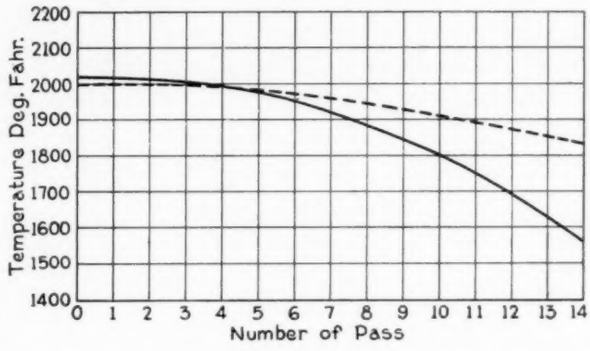


FIG. 18—Curve showing realtionship between temperature of steel and passes for either continuous or semi-continuous mills.

deg. F. to 1800 deg. F. Naturally the temperature range varies with the different types or arrangements of mills, as indicated by the curve Fig. 18, which shows the relationship between the passes and temperature of the steel for either continuous or semi-continuous mills. This data of course is only approximate and simply indicates to us the general tendencies. It has been stated that, owing to the rate at which work is done on the metal in a continuous rod mill, the temperature can actually be increased as the rod progresses by limiting the amount

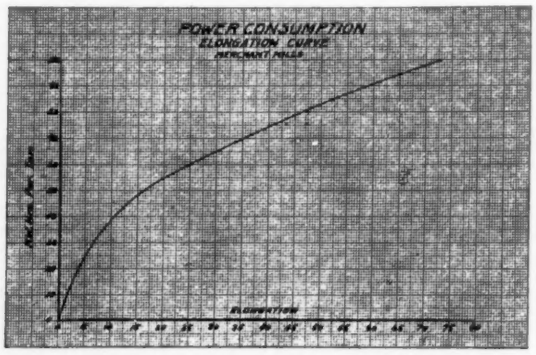


FIG. 19—Power Consumption—elongation curve for merchant mills.

of cooling water on the rolls. This, however, is not done in practice because of the effect that such high temperatures may have upon the surface of the finishing rolls and hence upon the quality of material produced. Temperature alone, therefore, has a great deal to do with the variations which we find in the power consumptions between rolling the same product on the same or different types of mills.

In giving power date it is always important to specify the size of billet from which the material may be rolled. Without this information the data is worthless. Also the layout of the mill and the manner in which it is operated must be known because of the effect these have upon the rate at which tonnage is produced. Consequently, at best power consumption can only be estimated rather than accurately determined.

We find from records on continuous wire rod mills the power in KW hours per gross ton when rolling No. 5 rod from billets 1¾" by 1¾", varying from 100 to 130 KW hours. This form of mill when producing large quantities of one size of product may have a yield as high as 90 to 95% for compartively long periods of time. The lower range in KW hours per ton may be expected upon a mill with alternating current motor or motors, mainly because of somewhat higher efficiency that such drives have over direct current. In spite of these facts most of the recent continuous rod mills have been built with direct current motors throughout.

The Garrett type semi-continuous looping mill will run 150 to 200 KW hours per gross ton when rolling No. 5 rod from billets 4" by 4". The variation here is greater than on continuous mills and even has greater range on the same type of mill. One mill in six consecutive days ranged from 156 to 172 KW hours per ton rolling all the same product and supposedly operating under the same conditions.

Power consumption for merchant bar is less consistent and less reliable than that for rolling wire rod. This is mainly due to the broad range of product in this class and also to the fact that there is a greater variation in the types or forms of mills and the manner in which they are operated. Mr. Blakeslee, in his article on the subject of Merchant mills appearing in the February, 1926, number of the Iron and Steel Engineer, has given us a curve Fig. 19 of power consumption expressed in terms of KW hours per ton per elongation. This curve, with full credit to Mr. Blakeslee, is being repeated here as a matter of convenience and, as stated by him, represents an average of tests made upon several merchant mills.

If we turn further back into the pages of our records we find in the April, 1925, issue of Iron and Steel Engineer some more specific data on some limited sizes of bar stock compiled by Mr. S. N. Roberts from the operations on the 8-inch combined rod and bar mill at the Atlantic Steel Company, Atlanta, Ga. As a further contribution to power data on merchant mills the writer wishes to include the tabulation of tests, Table II, taken by Mr. W. W. Garrett on the 11-inch merchant mill at the Fairfield Works of the Tennessee Coal, Iron and Railroad Company. This mill has already been covered in the general descriptions earlier in this discussion.

TABLE II Power records covering several sections of merchant bar, rolled on 11" merchant mill, Tennessee Coal, Iron and Railroad Company, Fairfield, Alabama.

Section from Billets 4"x4"	KWH/Ton at 1500 HP-16" Rougher	KWH/Ton at 1500 HP 12" Kraemer	KWH/Ton at 1250 HP 12" REPEATER	KWH/Ton at 500 HP Finisher	Total KWH/Ton Main Motors
47/64" Plain Round	25.64	17.70	19.02	6.86	69.22
39/64" " "	27.75	29.01	25.08	9.93	91.77
31/64" " "	35.85	42.30	33.70	12.95	124.80
½" Havemeyer Round	31.99	39.10	28.75	12.77	112.61
½" " Square	29.55	34.65	20.65	10.25	95.10
½" Dudley Square	29.55	32.99	29.55	9.32	101.41
5/8" Havemeyer Round	24.79	23.81	17.13	10.08	75.81
¾" " "	25.00	16.47	20.50	8.78	70.75
⅞" " "	23.20	16.00	8.80	9.84	57.84
1" " "	30.70	17.06	9.09	9.89	66.74
1" Dudley Round	22.45	16.85	5.62	5.51	50.43
1" " Square	19.45	20.39	7.41	6.02	53.27
1" Plain Round	26.20	15.16	8.96	7.32	57.64
1⅛" " "	18.09	11.70	6.38	7.14	43.31
1⅛" Dudley Square	19.76	18.60	8.14	6.51	53.01
15/16" Plain Round	26.48	17.65	6.61	6.47	57.21
¾" " "	28.59	19.49	18.19	8.18	74.45

MOTOR CAPACITIES

Motor capacities are usually specified by the mill builders. The motor manufacturers, also, are in position to recommend to a fair degree of accuracy motor ratings if a complete schedule of rolling together with a full description of the mill, the method of operation, and the tonnage expected, are given. The conditions are too varied to permit setting any but general recommendations which have herein been given. In many cases the motor ratings in horsepower and speed can be only roughly estimated. Experience and good judgment are relied upon to a great extent. This probably is more true with reference to merchant bar and rod mills than any other types because of the wide range of product coming under these classifications, and because of the variable conditions under which the mills may operate.

*Factors Governing the Purchase of Coal**

By MORGAN B. SMITH†

Leading Factors Entering into Coal Selection—Purchase on a Specification Basis—Suggestion for Coal Contract Form—Suggestions for Study of Coal Mining Districts and Individual Mines.

INDUSTRIAL steam generation is now emerging from that long primitive period in which steam-plant operation was merely operation and in which careful coal selection and purchase, beyond consideration of the delivered cost, was seldom seriously considered.

Industry, the country over, is awakening to the savings to be gotten by **proper coal selection,** the greatest single factor involved in efficient steam plant operation.

Significance of Plant Efficiency

In this country industrial steam plants at large show an average boiler and furnace efficiency of 56 per cent, whereas 70 per cent may reasonably be expected. Careful coal selection followed by comparatively inexpensive plant betterments and more intelligent plant operation will bring about this increase in efficiency.

In a plant burning, say, 100,000 tons of coal per year, a saving of 14 per cent in fuel will amount to 14,000 tons, which at $4 delivered price per ton, represents a saving of $56,000 per year. This is equivalent to $933,300 if capitalized at 6 per cent.

Purchasing Versus Plant Operation

Steam plant efficiency can be raised only by co-ordinating (a) coal selection, (b) better plant operation, (c) betterment and proper maintenance of plant, (d) installation of instruments for the guidance of plant operators and for obtaining comparative operating data, and (e) adequate records of plant performance.

Thus, it is apparent that coal selection and purchase cannot be divorced from plant operation unless plant efficiency is considered of little moment. Purchasing in general cannot be efficient without thorough co-ordination of its function with that of plant operation and management. Real team work among men of widely different training, experience, knowledge, and points of view must be attained before maximum efficiency can be gotten.

Purchasing agents are urged to line up their function in coal selection and purchase with that of the plant engineer and the boiler plant operator. They should also consult fully with coal producers and sales agents.

How, then, shall we tie in these several functions?

COAL SELECTION

Coal selection is probably the most important single factor because only through proper selection can coal best suited to existing plant equipment be bought. Therefore let us consider the leading factors entering into coal selection.

1—The Boiler Plant

a Type and size of boilers.

b Volume and shape of combustion chamber.

c Firing methods, such as by hand, stokers, pulverized coal, wood refuse, coal and wood refuse, etc.

d Type of grates, stokers, pulverized-coal apparatus, etc.

e Average rating at which boilers are operated and duration of operation periods, including banking, and minimum and maximum ratings.

f Type of furnace construction, such a plain brickwork, air-cooled or water cooled and combinations of cooling methods.

g Type of refractories used in furnace construction, especially with regard to resistance to fluxing and erosion; a matter of **maintenance cost** and also involving the question of continuity of plant operation.

2—The Coal

a General characteristics of the field or district and seam where the coal is mined should be determined, including analyses of **delivered** coal from each district and seam considered.

b The coal should be studied particularly relative to its content of volatile combustible matter, ash, and sulphur. Considerable study should be made of the ash-sulphur ratio, as there seems to be a relationship (as yet undetermined) between this ratio and the fusing point of the coal ash. Considerable data seems to indicate that this relationship is based on the content of ferrous sulphide (FeS) a dark gray crystalline substance and iron disulphide (FeS_2), a yellow crystalline mass. The former is difficultly seen in the coal structure because of its color; the latter (yellow)) is in contrast with the coal structure color and so is often readily detected.

c The burning characteristics should be determined at all usual ratings of boiler operation, to determine coking properties, clinkering tendency, ability to carry the load, etc.

d The three inerts in the coal structure—inherent moisture, ash, and sulphur—should be considered in order to determine the cost of true combustible content of the coal.

e Comparative costs of true combustible matter in several coals, including price at mines, freight, and handling charges, should be set up to determine which is the best coal relative to cost, always bearing in mind the plant equipment.

f Labor costs for conditioning of fires and for ash handling should be considered.

*To be presented at A. I. & S. E. E. Convention, June 25-28, 1928.

†Engineer, General Motors Corp., Power & Maintenance Section, Detroit, Mich.

g Such coals may then be comparatively rated with respect to the amount of heat recoverable from each of them in the form of steam.

h By considering together the total delivered cost and the rating assigned to each coal we can determine a **base cost** for each coal, which logically may be the cost per 1,000,000 B.t.u. in each coal or may be the cost of 1000 lb. of steam in each case, or may follow a purely arbitrary scale.

i Such study should be followed by thorough service tests of several coals which have passed preliminary examination. Tests should be sufficiently exhaustive to determine what may reasonably be expected from each coal in regular plant operation covering all operating conditions.

j Comparative study and tests and gradual collection of coal data will eventually enable a purchasing agent to choose his coals for the particular steam-plant equipment with a high degree of accuracy, speed, and economy.

Eventually purchases will be limited to coals of certain well-defined characteristics obtainable in two or more districts, after which coal selection involves only the best market value conforming with the desired characteristics.

To make such a system workable we must systematically collect data on individual coals, which data then becomes capable of exact appraisal in advance of purchase.

k Too often coal buying is limited to one field or district. In time because of such limitation the buyer finds himself with but one source, accompanied by non-competitive prices and the chance that supply may fail in times of emergency. This all leads to limited experience with coals, whereas prudence indicates the value of broad experience with diversified sources, which comes only by trial of coals from different fields.

l Price relationship even among selected coals is in a constant state of change, and the ratio of price to test results soon becomes obsolete. The answer to such a condition lies in the installation and use of proper instruments in the boiler room so that the boiler plant will be in a state of daily test—the watchdog over coal selection and purchase, plant maintenance, and capital investment.

3—The Coal Mine

Each mine should be studied relative to its location, district, and seam, methods used for coal preparation, shipping facilities, shipping point, originating railroad and routing, freight rates, mine output, and coal reserves.

The labor question is very important. Is the mine unionized or not? What is the probability of mine shutdown?

Each selected or approved mine should be inspected at regular intervals, especially with regard to coal preparation. Is the preparation equipment adequate or not? Is it improved from time to time in step with changes in the coal seam, especially with regard to seam "partings"? Poorly prepared coal will contain more or less avoidable ash, which will involve higher freight and handling costs in terms of combustible matter shipped, as well as lower operating efficiency in the steam plant.

4—The Coal Vendor

The vendor, preferably a producer or direct sales agent, should be studied and rated with regard to his ability and intent, based on past performance, to deliver coal from specified mines as per contract or "spot" purchase agreement.

The vendor's financial stability should also be considered. Will he be in business one year hence or five years—or is he a "fly-by-night" operator working a mine merely to take advantage of a temporary demand?

What has been his attitude toward his customers relative to productive wage increases at his mines? Has he made unjustifiable demands, or has he been reasonable in such matters? A coal buyer should always protect himself against such practices, remembering of course that productive-wage increases are often justified by conditions in the field. No buyer should pay more than the increase paid to true productive labor at the mine. Non-productive labor should not be considered. In several instances it has been determined that productive labor constitutes 52% of all labor employed.

5—Check on Quality of Coal Delivered

As a protection against receipt of coal poorer in quality than that specified in the purchase agreement, the buyer should insist that regular and representative samples be taken from the delivered coal for test purposes. Samples should be taken in accordance with generally accepted methods such as are prescribed by the American Society for Testing Materials. Unless a sample is representative of the coal in question the results of tests will be worthless.

Shipping points should be checked regularly even though we know that coal from several mines is shipped from the same billing point.

Many producers and vendors have so-called "headliner" mines upon which they depend to sell their inferior coals. Constant checking of delivered coal for quality and shipping point is absolutely essential.

6—The Effect on Size of Coal on Price

It is a fairly general practice to sell 1⅛ in. and 1¼ in. slack as 2 in. slack. The buyer should know that 1¼ in. slack as a rule contains approximately 25 per cent less fuel value than the 2 in. slack. By fuel value, we mean the overall return gotten from a coal in the form of steam and its cost, not merely a statement of analysis of coal received. The vendor figures that if he can cut from the 2 in. size to the 1¼ in. size he has added 15 cents per ton to his profit, which the purchaser of course pays.

7—Delivery in Cars Specified

Considerable expense can be saved by carefully specifying the type of car in which shipments shall be made. A plant equipped with track hoppers or trestles should specify Ralston hopper-bottom cars or their equivalent, whereas such cars are not suitable for delivery to a plant without track hoppers or trestles.

8—Routing and Scheduling of Coal Shipments

Proper routing and scheduling of coal shipments will save considerable handling expense. Each order for coal should contain definite routing instructions and a shipping schedule.

9—The Purchase Order or Contract

Too often an order for coal specifies tons only, whereas it should also state the mine from which shipments shall be made, the seam, the shipping point (name of same with county and state also named), routing, class of railway cars, etc. This may involve a little additional clerical expense, but when completed the buyer has a definite legal contract and he can refuse substitute coal if he so desires. Without such an order or contract the buyer has no legal redress under emergency conditions or on a rising market.

Confirmation of each order should be insisted upon by the purchaser, and such confirmation should be carefully checked against the original order as soon as the confirmation is received. It is an acknowledgment by the vendor that he not only understands the contents of the order but also accepts it in its entirety. If the vendor's confirmation and your order agree, or are made to agree if necessary, you will not have to call in your legal department to straighten things out.

10—Price Agreements

Orders should be placed at a definite price, especially in the case of "spot" orders. Contracts may be made, and often are, on a sliding scale of price. In either case the order or contract should contain a clause under which no increase or decrease in price can be made during the life of the order or contract unless the purchaser is given at least ten days' written notice prior to such price change, and only after receipt by the vendor of purchaser's written acceptance of such price change, and furthermore, the purchaser should have the right within the ten days to cancel the order or to transfer the unshipped tonnage to another approved mine located in a district wherein such price changes have not been found necessary. The clause should also make it obligatory that the vendor shall notify the purchaser of any subsequent price reductions so that the purchaser may benefit thereby. This all refers to necessary increases in productive-wage scales, often reflected in the price of coal by demands on the part of the vendor that the purchaser pay the contract or order price plus the productive-wage increase. Obviously the buyer should determine the justifiable increase in price.

11—Checking Car Shipments

Checking of shipping points is of value to the purchaser who is desirous to limit his purchases to a single mine or to a certain group of mines.

A system which is simple and works well may be outlined as follows:

a Original requisition is filed with a copy of the purchase order.

b Freight bills received are forwarded to the man in charge of unloading the coal. After he has inspected and unloaded the coal and is satisfied that the shipment is O. K., he forwards receipted freight bills to the filing room.

c In the filing room the freight bills are placed with the order and requisition.

d Upon receipt of the vendor's invoice the comptroller calls for the complete file, and checks the invoice against the records to establish the shipping point and mine against those specified.

12—Co-ordination of the Purchasing Function and the Power Plant Operating Function

The points of view of these two functions, each of which in its way may be correct, are often widely different and too often irreconcilable.

For example, the purchasing department with consent of the management, may yield to insistence of the operating staff upon the purchase of a certain coal, which as a matter of fact can be duplicated in every essential respect at a lower price. On the other hand, the reverse may be true, and a management with a prejudice for low unit cost of material supports the purchasing department in the selection of low-priced coal of such a character that resulting operating losses more than offset any apparent but unreal gains made in buying. These two extremes must be brought together in such a way that the coal buyer will see and understand the viewpoint of the plant operator; that the latter shall appreciate the purchasing department's problem of coal selection and purchase; that the management will understand why the plant operator has asked for plant betterment, etc. The joint success of such procedure has much to do with plant management, not the least of whose problems consists in keeping capital investment within bounds.

13—Approved Coal Mines and Vendors

In one form or another, every coal buyer should develop a list of approved coal mines and vendors. The number of mines will depend on the coal tonnage involved, but in any event they should provide diversity of sources, i. e., districts and seams. Such a list should be kept up to date and alive. It may in time consist of (a) several "permanent" or proved sources, (b) a few doubtful sources more or less subject to rejection, and (c) of a few new sources on trial for say one year or longer if advisable. Sources under (a) are retained subject to continuous satisfactory service; those under (b) are likely to be dropped unless markedly improved service is shown during a

period of one additional year on the list; those under (c) are under close observation and the service they render will determine whether they will advance in rating or be dropped.

There is little to be gained by continually switching around from vendor to vendor or from mine to mine, but the purchasing agent should switch around until he has been able to develop several dependable sources to assure continuity of supply and competitive purchasing.

Purchasing Agents should cultivate their coal sources; should give courteous reception to the sellers sent out by such sources. Hearings of this sort are as a rule mutually advantageous. By so doing the buyer will soon develop sources of dependable information and will keep alive to the many problems faced by the coal producer and seller.

14—Classification of Coals

There is a movement on foot whereby coals are to be "classified," and such a movement is one in the right direction. Let us all hope that it does not stop with a mere geologic grouping of coals, but goes farther and tells us what the burning characteristics are; what the behavior of coals will be under conditions of high rates of combustion, etc. In other words the purchasing agent and the plant operator need competent and unbiased advice as to which coals will suit their plant equipment, and they do not much care on the face of it whether a coal belongs to this or to that geologic age.

The A. S. M. E. Special Research Committee on Fuels embraces among its subjects one which we hope will answer this question, namely "utilization research."

Furthermore, while this "classification" work is under way, we believe that those doing this thing might well take the time to gather together the scattered data on coals, preferably in handbook form, for the ready use of those purchasing or burning coals. The A. S. M. E. Committee recognizes this fact indirectly in one of its research subjects, namely, "correlation of existing information."

It is up to each and every one of us purchasing and utilizing coals to assist in the tremendously important task undertaken by this Committee should we be called upon for assistance.

15—Purchase of Coal on a Specification Basis

A specification covering the purchase of coal to be a success must be workable; and to be workable it must be equitable; and unless it is equitable it will not hold as a legal contract.

A bonus and penalty clause in the case of industries will work well provided that penalties do not overtop bonuses. The value of such clauses is open to serious doubt. In almost every instance which has come to the author's attention they result in ill will between the parties to the contract. There are no doubt exceptions. In the long run, coal of reasonably uniform quality can be purchased without such clauses at prices which offset any gain to be made through bonus and penalty provisos in the contract.

Following are a few typical specifications. The author believes that the most practical specification is one covering coals of known general qualities and laying special stress upon preparation of such coals, as under 15-c herewith:

(a) A large automobile plant buys its coal on a simple specification containing a bonus and penalty proviso. In this case buying has been "successful." It is admitted that bonuses and penalties are practically in balance all the time, and both parties to the contract are happy. Briefly, this specification reads as follows:

The coal shall be a good grade of mine-run coal free from bone, slate, dirt, and excessive dust, and of such a nature that when crushed, it will flow freely. It shall not take fire spontaneously while stored. The chemical and physical properties of the coal, when determined on the basis of an air-dried sample shall be:

	Minimum	Maximum
Moisture, per cent	0	2
Volatile matter, per cent	30	37
Fixed carbon, per cent	55	60
Ash, per cent	6	8
Sulphur, per cent	--	2.0
B.t.u. per lb.	13,500	14,500
Fusing point of ash not less than	2700° F.	
Ratio of volatile to fixed carbon	0.50	0.65

Payment for coal will be made upon the basis of the agreed price, corrected for variations from the specified standards in heating value and ash contents.

When the variation in B.t.u. exceeds or is below the specified amounts, the correction in price will be a proportional one.

Premiums on ash content will be as follows:

Ash content per cent	Per cent premium, f.o.b. Destination, on purchase price
5.00-5.99	1
4.00-4.99	2
3.00-4.00	3

Penalties on ash content will be as follows:

Ash content per cent	Per cent reductions, f.o.b. Destination, on Purchase Price
8.01-9.00	1
9.01-10.00	2
10.01-10.50	4
10.51-11.00	8
11.01 or over	Special adjustment

When price adjustments for both B.t.u. and ash content are necessary, that due to B.t.u. variation shall first be determined, and that due to ash variation shall be figured on the price as revised for B.t.u. content.

(b) Another automobile manufacturer buys his coal satisfactorily on the following specification, without a bonus or penalty proviso.

	Mine Run	Nut and Slack
Inherent moisture, max. per cent	1.5	1.5
Volatile matter, max. per cent	35.0	35.0
Fixed carbon, per cent	56.5	56.5
Ash, max., per cent	7.0	7.0
Sulphur, max., per cent	1.0	1.2
Oxygen, per cent max.	8.0	8.0
B.t.u. per lb. as received minimum	13,900	13,750
Softening point of ash, min. deg. fahr.	2,750	2,600

(c) A very large plant limits its specification to a careful statement reagrding preparation of coal because they know that the coals on their approved list are satisfactory in every way **if properly prepared.** This statement is as follows: "Coal furnished shall be prepared in such a manner that material foreign to coal, **in, above,** or **below** the seams, shall be eliminated as far as possible. Coal specified shall not contain more than 8 per cent of ash. If the ash content exceeds 8 per cent the buyer may refuse to accept the coal in question." This simple specification is still working well after approximately 15 years' duration.

16—Suggestion for a Coal Contract Form

The ordinary material-purchase form is seldom suitable for writing coal contracts. A form which works well is as follows:

STANDARD NUT, PEA AND SLACK, AND MINE-RUN COAL CONTRACT

(Name of Purchaser)_____

Agreement entered into this_____day of_____19__, between

_____

hereinafter referred to as the "Seller" and_____

_____

hereinafter referred to as the "Buyer" WITNESSETH:

The Seller agrees to sell and the Buyer agrees to purchase, at the price agreed upon subject to the following terms and conditions, COAL hereinafter referred to as the "Article."

Specified Sources and Description

		Shipping Point		
Mine	Seam	Town	County	State
1_____	_____	_____	_____	_____
2_____	_____	_____	_____	_____
3_____	_____	_____	_____	_____
4_____	_____	_____	_____	_____

Quantity and Size—Net Tons of 2,000 lbs_____Size_____

WEIGHTS OF SHIPMENTS—

Railroad weights shall govern tonnage shipped, excepting that if later such weights are found to be incorrect by the Railroad and by the Buyer, then such corrected weights shall apply.

Price for Net Ton of 2,000 lbs., f.o.b. Mine_____$_____

Terms of Payment_____

Destination and Routing_____

_____

SCHEDULE OF SHIPMENT—Delivery shall be made between the date hereof and _____ as may be specified from time to time on Buyer's regular Purchase Order, and in accordance with the requirements of Common Carriers. Shipments will be made **where directed by Buyer** in the case of embargoes on shipments to point of delivery herein specified.

RAILROAD CARS DESIRED_____

PREPARATION OF COAL. (As in Specification c, Par. 15 above).

SPECIFICATION. May or may not be included as desired by Buyer.

SELLER'S PERFORMANCE. If production at specified mines falls below the amount herein specified, the Seller shall ship whatever coal is produced. This shall not, however, authorize the Seller to ship less than the specified amount when production

OUTLINE SPECIFICATION OF COAL

PARTIES TO CONTRACT
- Seller
- Purchaser
- General and Specific Clauses
  - Producer's or seller's bond—Surety Co.
  - Coal to be furnished
    - Trade name
    - Region mined—state mines, seams; shipping point—town, county, and state
    - Size limits, if any
    - Quantity
      - Per cent allowed for varying requirements—pro rata tonnage in case of strikes
      - (Max.) Reserve for test purposes—right to buy on open market—per cent of max. quantity
  - Purchaser's Option
    - Rights in case of seller's failure to fulfill contract—annulment of contract
  - Shipments
    - Notice to seller as to requirements
    - Delivery
      - When—period
      - Where—tracks at yards
      - How—types of cars desired
      - Routing
    - Weights
      - Railway bills expense to purchaser
      - Purchaser's weights
  - Payments
    - Price
      - Mines—productive-wage changes
      - Freight—changes in rates—how adjusted
      - When to be made—monthly or otherwise
    - Basis-quality
      - Specification
        - Bonus and —penalty clause
        - Scale of —price per ton
        - Sizing
        - B.t.u. dry coal
        - Per cent ash and fusing point
        - Volatile
        - Fixed carbon
        - Sulphur
        - Nitrogen
        - Inspection clause
      - Tests for Quality
        - Made by whom
        - Test to be made named
          - When
          - Where
          - by whom—seller—purchaser—referee
          - Methods to be followed
            - Sampling
            - Analysis
        - Test reports
          - Forms
          - Sent to whom

equals or exceeds the amount herein specified. (This is a somewhat drastic clause but is workable and in force in several instances. If this clause is found too drastic, terms and conditions of the "Standard Coal Contract, Form A or B," recommended by the National Association of Purchasing Agents, may be used. Many coal vendors provide their own contract forms which always include a vendor's performance clause, generally designed for the vendor's protection.)

NON-PERFORMANCE EXCUSED. The Seller shall not be responsible for delays or defaults in deliveries nor the Buyer for failure to receive, if occasioned by wars, strikes, fires, the act of God or the public enemy, labor or transportion difficulties or other causes beyond their control.

SELLER'S WAGE SCALES. The price herein specified is governed by the Seller's productive-wage scales in force at the time this contract goes into force, namely, Seller's Base day-wage scale is $..... Seller's hourly wage scale is $..... for productive labor, Seller's tonnage wage scale paid to loaders is $..... Increase in price over that herein specified shall take effect only upon Seller's written notice to the Buyer at least ten days prior to such increase and upon Buyer's acceptance of same.

Increase in price shall not be effective until shipment shall have been completed which were specified before such written notice is sent to the Buyer by the vendor.

The Buyer will not consider any increase in price over that specified in this contract unless such productive-wage increases are general in the district wherein the specified mine or mines are located.

In the event of such increase, the Buyer may cancel this contract or shall have the right to accept unshipped tonnage covered by this contract from a mine or mines, as agreed upon between Seller and Buyer, at which productive wage increase have not been made. The Buyer shall receive the benefit of any and all subsequent reductions in productive wage scales and the Seller shall at once notify the Buyer of any and all such reductions upon their consummation.

The Buyer shall have access to Seller's books in case of dispute in order to determine the amount of increase per ton justified by Seller's increase in the cost of productive labor.

INSOLVENCY AND CANCELLATION. (The usual legal form.)

REMEDIES, Etc. (The usual legal form.)

PRIVACY OF CONTRACT. (The usual legal form.)

NON-ASSIGNMENT OF CONTRACT. (The usual legal form.)

IN WITNESS WHEREOF, the parties hereto have executed these presents in duplicate the year and date first above written.

.....Seller .....Buyer

By..... By.....

17—Suggestions for Study of Coal Mining Districts and Individual Mines

(a) Determine the relationship between ash and B.t.u. content.

(b) Determine, eventually, the effect of sulphur upon the softening point of coal ash (if such a relationship exists).

(c) Check up the preparation at the mine of coal delivered to your plant by watching the variation in ash content.

(d) Check up with your plant engineer the performance of purchased coal in your steam plant. He is in a position to assist you in your problem of coal selection.

(e) Study your vendors relative to their performance on contracts and on "spot" orders. Study their attitude toward you, one of the outlets for their product. Study their general business policy. In time you will develop a list of thoroughly dependable sources.

(f) Develop a diversified list of sources to protect yourself against emergency conditions. Study routing of shipments as well as freight rates.

Much of the foregoing may seem to relate more to the steam plant and the chemical laboratory than to purchasing, and, frankly, it is the author's intent to show that the purchasing function cannot operate effectively unless it ties in with steam-plant operation. And steam-plant operation cannot be most highly efficient unless the plant operator ties in with the purchasing function in the selection of proper coal. And, finally, of utmost importance, tie in both your purchasing function and plant operation function with the coal producer or seller with whom you are dealing. You will find him generally able and anxious to help you.

*Present Practices in Connection with Motor Driven Rollers**

By J. C. DOBELBOWER†

THE group type of motor drive has been used on roll-out tables for many years. Satisfactory results have been obtained with this drive but like many other applications it has some faults.

A few years ago the idea of driving the rolls with individual motors was conceived and tried out. This type of motor has been given the nomenclature of "Roll Out Motor." It has met with success and at the present time there are numerous tables in different mills now equipped with this type of drive.

*To be presented at A. I. & S. E. Convention, June 25-28, 1928.

†Mech. Engr., Crocker Wheeler Elec. Mfg. Co., Ampere, N. J.

The group drive, whether of the cable and sheave type, or bevel gear type, lacks flexibility in that the individual rollers cannot be controlled; in case of motor trouble, breakage of cable, or gears, the entire table is out of commission. With the roll-out motor drive the failure of a driving motor affects only the one roller—in fact a number of motors in the train could fail without a shut down of the table. This also permits shutting down some of the motors to produce a drag on the speed of the strip or bar if desired.

There are also fewer bearings to lubricate than on the group drive which means less maintenance cost and fewer chances of trouble.

There are several different designs and applications of roll-out motors as follows:

A motor of the same general construction as a general purpose motor. This consists of a stator frame with feet or ears arranged for mounting in the particular roll-housing on which it is to be applied. Mounted on and fastened to the frame are the end shields or bells in which are mounted the anti-friction bearings. The rotor on shaft has an extension on one or both ends depending on the type of table it is to serve. The rollers are mounted on the shaft extensions in the same manner as a pulley on a general purpose motor. While this design is of the same general construction as a general purpose motor yet due to its duty it is made relatively much heavier and more rugged.

This type of motor when used with roller on one end only is lubricated in the standard manner through the enclosing cap. The roller end of motor may have a pipe carried around the frame to the exposed end so that grease can be applied to both bearings from the one end.

When rollers are mounted on both ends the best method of lubrication is through holes drilled in the ends of shaft opening into the grease chamber.

Another type is that described by Mr. MacCutcheon of the Reliance Company some time ago. This is of a very special construction in which the rotor is the outer member and the stator is the inner member. The rotor is mounted directlv in the roller and the stator is mounted on the shaft which is held stationary; the outer race of bearing rotates and the inner race is stationary. This construction is of course just the reverse of standard construction of motors.

There are several modifications of the first type described but they are along the same lines as far as design is concerned. One modification is exactly the same, but instead of the rollers being mounted on the shaft extension they are driven through flexible couplings.

A second modification of the first type is of the same design but without a shaft. The rotor in this case is mounted on an extension of the roller shaft. The end shields or bells are used only as enclosures since the only bearings are those on the roller shaft.

With any of the types of motor for roller drive it is essential that the insulation throughout be such that it will stand up under the heat obtained and all parts must be of extra rugged construction. In installing roll-out motors it is also essential that each motor be protected by an overload relay or fuse to prevent roasting out in case the motor is stalled due to jamming or any other abnormal condition unless the motor is designed to permit stalling.

The power for driving roll-out motors is best obtained by the use of a motor-generator set. This should consist of a variable speed D. C. motor driving an alternator. By the use of this combination the speed of the alternator can be varied, thus changing the frequency and voltage of current delivered to the roll-out motor. This permits the operator to control the speed of the strip or bar on the table. One of the frequencies and voltages should be made the same as that of the general mill supply. If this is done it is then possible to swing over to the mill supply in case of trouble with the motor-generator set.

Probably the main reason why individual driving of rollers did not come into general use sooner was due to the fact that anti-friction bearings were the exception and not the rule on electric motors. There have been some installations in service for a good many years with motors having sleeve bearings but I feel that this type of drive is one that should have a motor with anti-friction bearings.

Roll-out motors of the general purpose design can, if desired, be ventilated. If this is done, however, it is necessary that clean air be supplied; the ventilation can be obtained by bringing the clean air in one end of the motor at the bottom and discharging it at bottom of opposite end. This type of motor however should not require ventilation as it is comparable to any fully enclosed motor operating in a hot place. The roll-out motor of the design where the motor is built directly in the roller is however a different problem; the motor, in this case, is subjected directly to the heat from the strip or rod being carried on the outer surface of the motor; thus heat is applied to the surface which, in the ordinary design of motors, is the surface from which heat is radiated.

While I have not investigated up-keep costs of group drive versus roll-out motor drive, yet I personally feel that there is considerable saving in the use of the latter. It is certainly true that the yearly replacement of cable as used in the group drive will pay for the repairing of a great many motors and the cable is only one of the parts that may fail. I will be interested in hearing a statement from some one who has made an investigation of this phase of the application.

There will no doubt be a number of the Mill Engineers who will stick to the group drive, for after all, the personal equation is a large factor in such problems as this. We, however, feel that the roll-out motor has proven itself and from the numberous inquiries regarding same we believe that the future will see most of the mills in the country equipped with individual motor drives on their roll-out tables.

*Boiler Pressure Above 500 Pounds**

By J. B. CRANE†

TODAY there are reported to be in operation and in course of construction fifty plants with a pressure of over 500 lbs. per square inch and of these three are for 3200 lbs. per sq. inch and fourteen between 1000 and 1770 lbs. per square inch.

The question of high pressure is, therefore, more than academic. It has been studied by many engineers and the theoretical economies to be affected have been proven by actual operation. It has, therefore, become a problem to be considered by all engineers interested in Power House Construction or operation.

Theory of High Pressures

With pressures under 500 lbs., we have practically reached maximum possible economies. With pressures of 450 to 500 lbs. the maximum temperatures modern materials have successfully withstood is 725 deg. to 750 deg. Fahr. When steam at these temperatures and pressures is introduced into a turbine, the steam becomes saturated or nearly so by the time the condenser is reached. Above 500 lbs., it becomes necessary to reheat the steam before introducing it into the lower stages of the turbine.

If we do reheat the steam, it introduces temperature stresses between the turbine stage from which the steam is withdrawn and the stage to which the higher temperature steam is readmitted and a better design results if the two stages are placed in separate casings. If separate casings are used a better design is obtained if the initial pressure is raised to 800 or 900 pounds, thus securing the maximum economy from the initial turbine and the reheater turbine. If the initial pressure is raised above 900 pounds a more efficient and economical unit is obtained by operating the high pressure unit at a higher speed and the reheat unit at a lower speed. It then becomes economical to build the initial turbine for a pressure of 1200 lbs. to 1400 lbs. and to use a standard turbine unit for the lower pressure.

The above applies to complete power houses. There is one other problem to which high pressure steam is even more applicable and that is where steam is used for process work. By adopting a high initial pressure and using the steam turbine as a reducing valve between the boiler and process all the power for use about the plant may be secured for the expenditure of less than one-half a pound of coal per kw.h. at the switchboard provided of course that the steam requirements for power do not exceed the steam requirements for process work.

The turbine manufacturers have kept step with the demand for higher pressure and systems have been developed to bleed the different stages of the turbine to heat the feed water to nearly the temperature required in the boiler and thus reduce the amount of steam going to the condenser and reduce the heat formerly lost in the condensing water. These are subjects for the turbine engineer to describe to you and my paper will be confined to the generation of the steam and its use about the plant.

*To be presented at A. I. & S. E. E. Convention, June 25-28, 1928.

†International Combustion Engineering Corp., New York, N. Y.

Reheat Cycle

Fig. 1 shows a method by which the steam is generated in two boilers at a pressure of 600 lbs. to 800 lbs., is heated to 725 deg. and enters a high pressure turbine; from the exhaust of the high pressure turbine the steam returns to reheaters located in the boiler setting, is again heated to 725 deg. and returns to the low pressure turbine at a pressure varying from 70 lbs. to 150 lbs. depending upon the load and is exhausted to the condenser. The reheater may be a protected radiant superheater as shown in Figure 2, a radiant superheater as used at Kansas City, a convection superheater as used at Philo, Crawford Avenue and in many other plants, or it may be a separately fired superheater placed at the turbine or a steam reheater located at the turbine and now

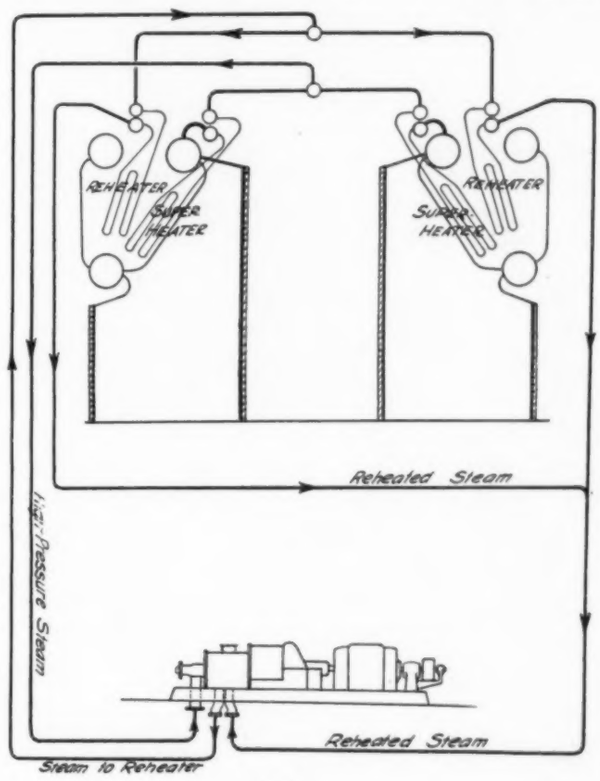


FIG. 1.

in use at Crawford Avenue. See Fig. 3. If the reheater is placed in the boiler, a drop of 15 to 25 lbs. results through the piping and superheater. If the reheater is placed at the turbine and live steam used for supplying the necessary heat, the pressure drop is at a minimum but the total steam temperature will be less than 600 deg. In this case, the high pressure steam condenses and is returned with the condensate from the condenser.

When used for process work, the reheater is usually omitted and we are now working on a proposal for an industrial process where the steam will be generated at 2,000 lbs. gauge with no initial superheat.

Pressure Limits

It is one of the properties of water that at 3300 lbs. pressure the heat in the water and the steam are the same and the water passes into steam with no ebullition. Benson, an English engineer, has taken advantage of this phenomenon to construct some boilers at this pressure. In order to provide against burning of tubes, on account of possible lack of circulation he pumps the water through the tube thus giving a forced circulation. The steam is then reduced in pressure, put through a superheater and used at 1500 lbs. to 1800 lbs. pressure. In this country we have tried to stick to natural circulation and Fig. 4 gives a curve based on buoyancy which indicates circulation troubles we may get into. This curve is constructed as shown in Table 1.

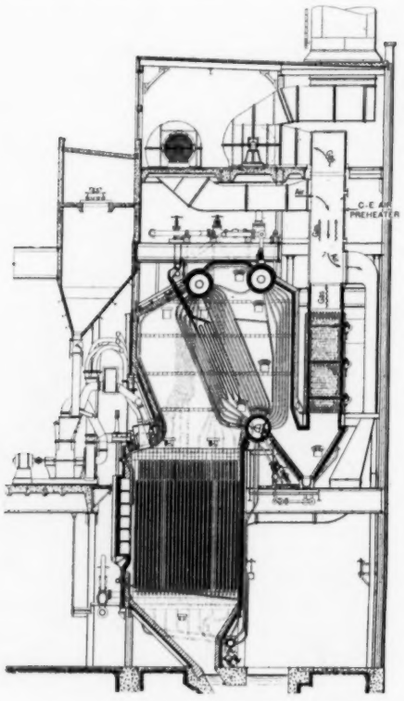


FIG. 2

TABLE I

Pressure Absolute	Volume of Cu. ft. per lb. Steam	Water	Each lbs. of steam displaced by lbs. of water	Resulting Buoyancy of Steam
200	2.287	0.0184	124	123
400	1.162	0.01945	59.9	58.9
600	0.769	0.0202	38.3	37.3
800	0.568	0.0209	27.1	26.1
1200	0.361	0.03245	16.1	15.1
1800	0.22	0.025	8.8	7.8
2400	0.14	0.0275	5.1	4.1
2800	0.10	0.03	3.3	2.3
3300	0.05	0.05	1.0	0.0

Assuming all boilers have the same distance between the bottom header and the water level in the top drum and the tubes are the same diameter and have the same slope then the speed of circulation will vary with the pressure and the speed of circulation for 1200 lbs. will be about ⅛ that for 200 lbs. and about ¼ that for 400 lbs. Will this slower circulation cause tube burnouts and more trouble than at the lower pressure? At Milwaukee the tubes across the bottom screen are 3″ in diameter and the total length between the bottom header and the top drum is seventy-eight feet of which approximately twenty feet is 15 deg. from the horizontal and fifty-eight feet vertical. On the horizontal tubes, the heat is directed from top so any steam pockets that do occur are on top which is the most severe condition that can be imposed. Yet in over a year's operation no tubes have failed since proper water condititoning was adopted. The tubes are 5/16″ thick which offers additional protection as the heat is more evenly distributed around the whole diameter of the tube than where thinner tubes are used and the heat passes directly through the tube to the water. The tendency for hot spots to cause blisters is lessened.

On another job operating at 800 lbs. pressure all tubes except the bottom and top are vertical. This unit has operated constantly for over a year at furnace combustion rates of over 30,000 B.t.u. per cu. ft. and no tube trouble has developed. The furnace is fired from four corners, so that many times the flame impinges directly on the tubes. Recently one of the top tubes of the screen was removed and a section in the top taken out for test and examination and there was no indication of overheating, the physical and chemical properties of the tube being exactly as when the tube was installed.

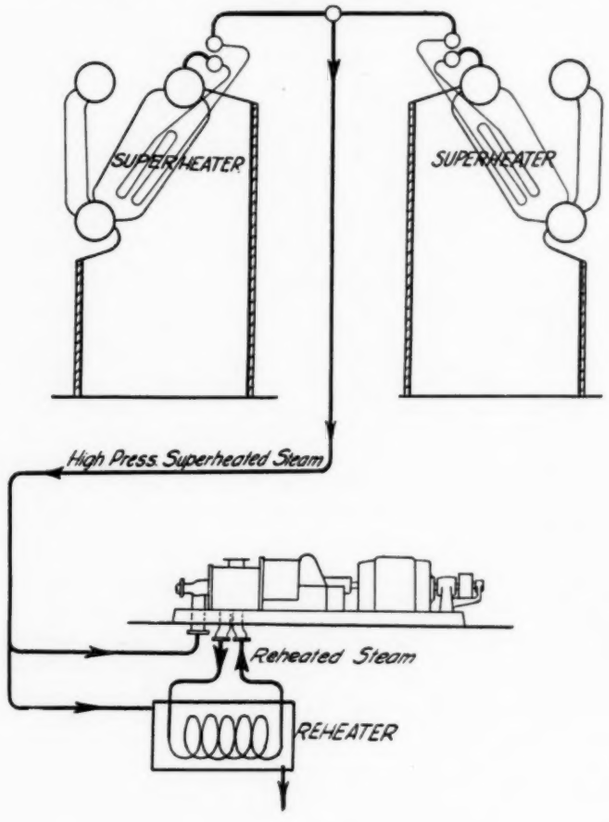


FIG. 3

It has been claimed by some engineers that the tubes in a vertical position are not as good as an inclined tube. The laws of physics teach that circulation will be more rapid with the vertical tube. The

other objection is that steam bubbles will tend to stick to the hot side of the tube and cause overheating. At higher pressures this will cause less trouble than at lower pressures because the heat is better distributed through the tube metal due to the greater thickness and experiments show that there is a local circulation set up in the water inside the tube tending to draw the steam bubbles away from the hot side of the tube. In one installation at 375 lbs. pressure we have four boilers with vertical tubes operating at 800% rating and no tube trouble has developed. In another case eight boilers with inclined tubes and 250 pounds pressure operating at 600% rating with no tube trouble.

The first 1000 lbs. pressure unit was installed in 1924 and the fact that there are four units in operation today at 1400 lbs. and others in course of construction shows the confidence that engineers have inspired in their backers. A reference to the curve shown in figure 4 indicates the buoyancy of steam at 2000 lbs. pressure is seven or approximately ½ what it is at 1400 lbs. pressure. Will natural circulation be satisfactory or will we have to go to forced circulation? Natural circulation may be satisfactory. We can only tell by actually trying it under service conditions. Why not at higher pressures?

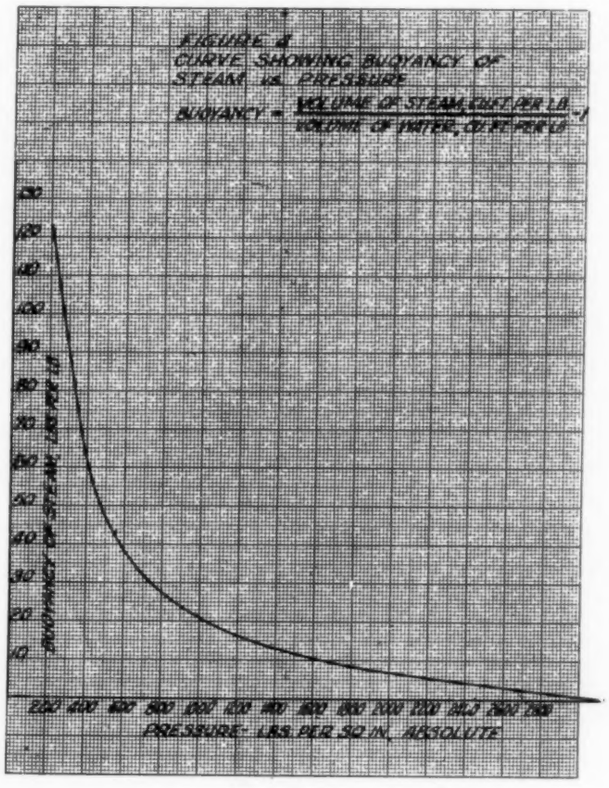


FIGURE 4
CURVE SHOWING BUOYANCY OF STEAM vs. PRESSURE
BUOYANCY = VOLUME OF STEAM, CU.FT. PER LB. / VOLUME OF WATER, CU. FT. PER LB.
PRESSURE - LBS. PER SQ. IN. ABSOLUTE

FIG. 4

Features of Construction

Tubes are the same as for lower pressures, except being of a heavier gage 3" tubes 5/16" thick are used in the vertical boilers and 2" tubes in the horizontal boilers. The tube seats have grooves 1/64" to 1/32" deep. The drums are 3" to 5" thick made of solid forgings with the heads necked in and forming an integral part of the shell. The manhole seats are formed on the inside of heads so that the pressure helps keep them tight. Nozzles over four inches in diameter are fastened to the drum by stud bolts with a tongue and groove joint and copper, monel metal or asbestos composition gaskets. Smaller nozzles are formed by rolling tubes into the drum and rolling the other end of the tube into a flange with serrations similar to the tube seat. Tube holes are counterbored giving a tube seat 1½" to 2" long. Nozzles are all formed by forging. Water columns are forgings connected to the drums by tubes rolled into the drum. Water columns are constructed of two flat glasses each side of the water space. They usually have mica between the glass and the water and a gasket between the glass and the washer which is held in place by stud bolts. A light is placed back of the gage class which gives a first class indication of the water level. Formerly these glasses were only seven inches long it being quite necessary to have a very even glass. Fig. 5. Now glasses can be secured thirteen inches long. It is necessary to put two or more glasses in series in order to get proper range of vision. When one of these glasses breaks, it does not fly out but becomes opaque. A new glass must then be installed. These are working out well in practice. There are good safety valves, blow-off and feed valves on the market for 1400 lbs. Screwed joints for the piping from the water column and gage glass are welded at unions and valves.

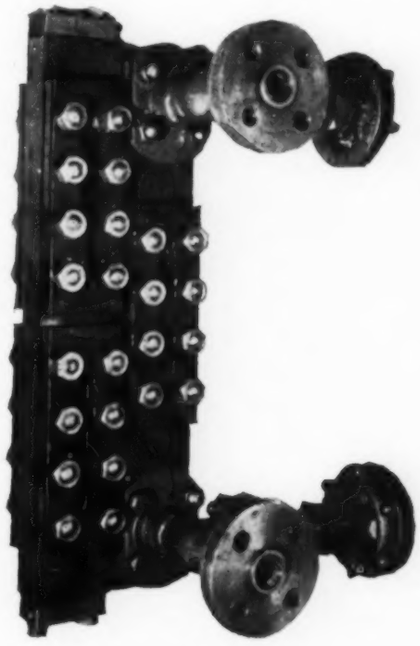


FIG. 5

Fittings

The American Engineering Standards Committee, sponsored by the Heating and Piping Contractors' Association, Manufacturer's Standardization Society of Valve and Fittings Industry and The American Society of Mechanical Engineers, have adopted a tentative American Standard for maximum working steam pressures of 250, 400, 600, 900 and 1350 lbs. per sq. in. (gage) and a temperature of 750 deg.

Fahr. They are now working on similar standards for 2400 lbs. pressure. Sargol welded joints, small tongue and groove, and a modified form of the mid-west joint are all being successfully used for these pressures. The chemical industry has been using pressures of over 3000 lbs. per square inch for several years and have blazed the way for high pressure piping. The high pressure turbine is placed as close as possible to the boiler or steam generator thus reducing the cost and extent of the piping to the least possible amount.

Feeding of Boiler

On account of keeping cost as low as possible, less water storage is provides than at lower pressures and the question of feeding the boilers becomes more of a problem than before. Probably the best method is to put three or more hand regulated small valves in parallel rather than use one large valve. These small valves can be manipulated much more rapidly than one large valve and can be set to take care of a steady flow of water to the boiler at a point a little under the minimum requirements and allow the regulator to handle the remainder of the minimum flow and fluctuations.

If possible distilled water should be used but in process work, the make up is usually greater than can be economically handled with evaporators and some water treatment must be used and a continuous surface blow-down system installed. By putting this hot water through heat exchangers, it is possible to operate for long periods with a very slight decrease in efficiency. The ordinary blow-offs are usually used only to empty the boiler. It is found that oxygen more readily attacks metal at these high temperatures and provision must be made to remove free oxygen from the water fed to the boiler.

If water walls are used, it would be well to install greater area in the downcomers and the risers from these walls, than would be necessary at lower pressures.

Operation

The operation of high pressure units is no different from that of low pressure units and a surprisingly small amount of trouble has developed especially when we consider the rapid development of these high pressures.

Great care is exercised every time a unit is down and a careful investigation made of all parts to see that no corrosion or deterioration has taken place.

Economies

The 1400 lbs. pressure units thus far installed have been superimposed on 350 lb. or 400 lb. plants. These plants already exist with boilers, turbines and auxiliary equipment for these lower pressures and in case of trouble the lower pressure plants will carry the load. By installing these high pressure units, it is only necessary to install the boiler with its equipment, the high pressure turbine and piping, no condenser is required. On this basis, and when passing all the steam for the station through the high pressure unit, a saving of 12% of the coal is theoretically possible and has been obtained in actual practice. It then becomes a question of first cost and operating cost as against the cost of coal. These will of course vary in different localities. Two plants are now contemplated in which there will be no low pressure boilers and the initial installation will consist of 1400 lb. pressure boilers only. Both of these plants are located on power systems having other plants or tied into other power systems. In one of these cases the initial cost of the 1400 lb. system was estimated to be about $110 per kw. as against $90 for a 450 lb. system. This cost included land, interest during construction and such items and with the prevailing price of coal it was estimated that the cost of operation would be in favor of the 1400 lb. pressure plant provided it operated at over fifty per cent yearly load factor. In your own particular industry you have many places where the question of securing sufficient condensing water is a serious problem and the power output could be increased approximately one quarter by the installation of a high pressure unit and passing the steam through this on its way to other uses. If additional power is required it is quite possible under these conditions that the first cost will be less than extending the present plant besides considerable saving in operation.

Size of Units

Boiler units with an hourly output of 250,000 lbs. of steam are in course of construction; larger units can be built with factors of safety as conservative as those now being used. Single turbines of 5000 kw. capacity are now in service and 10,000 kw. capacity designed and soon to be constructed. The central station and other industries have been quick to realize and take advantage of this development. The Steel industry usually alert for anything new, that has merit will not be far behind.

---

*Steel Mill High Tension Practices**

By F. O. SCHNURE†

STEEL Mill high tension practices should not differ materially from those practiced by Public Utility Companies. The ideals are the same, that is first, the protection of human life, second, the preservation of operating equipment, and third, continuity of service. In some respects the average steel plant has the advantage over a large power system in that the territory involved is restricted and the system is therefore easier to service and inspect.

Safety can only be attained by the co-operation of every one concerned with the operation of high voltage circuits. It follows then, that one person only, must be designated to give switching orders. This person must be available at all times of the day or night, so that in reality a "position" is in-

*To be presented at A. I. & S. E. E. Annual Convention, June 25-28, 1928.

†Elec. Supt., Bethlehem Steel Co., Sparrows Point, Md.

trusted with this responsibility. Power systems call this man a "Load Dispatcher." Steel Mills may use the same designation applying it to a responsible foreman available at all times, or designating the operator of the main station or sub-station as the responsible party through whom all switching must be done.

Records in the form of a station log must show a chronological statement of every important operation. Simplicity and brevity should be the keynote of all switching orders and records.

All circuits must be designated by a number or by a definite name. Switching orders must refer to this number or name.

Normal operation of a steel plant power system constitutes a "set up" of circuits and equipment that follows a routine in switching. Deviation from this routine, other than the normal switching concerned with individual mill operation, must be authorized by the person responsible for the routine. Assuming then, that it is desired to remove a line or piece of equipment from service. Depending on its importance in plant operation, authority may be issued directly by the Electrical Superintendent or by some man responsible in the organization, directly to the so-called "Load Dispatcher." The dispatcher first makes a record of the request and its originator on the station log.

If for future operation, this request for switching is held open on the load dispatcher's desk until the time set, so there will be no conflict with other future switching orders.

If for immediate operation, the operator or assistant performs the switching and if the request has been made by phone, reports back over the phone to the originator, that the switching has been completed.

If the switching order concerns an outside substation he transmits the order to the proper substation making a record on the station log, and when the substation operator reports back to him that the switching has been completed, he transmits this information to the originator of the request.

A caution tag shown below is then attached to the control switch and is not removed until the line or equipment has been reported clear and ready for service by the same man who ordered it out of service. If more than one gang is working on the job, caution tags for each gang are attached to the switch. In the event of the originator of the request being relieved by another he must transfer this authority to his relief through the load dispatcher and the caution cards must be marked accordingly.

In the event the originators fail to clear the caution tags the line must be patrolled or the equipment inspected before switching is done. However, violation of this clearance rule is subject to discipline.

Apparatus or a line once cleared for repairs must first be tested to establish for a certainty, that it is "electrically dead" if visual inspection of the disconnecting switches is not feasible. This testing can be done by any of the various detector sticks developed for such work.

After testing, suitable grounds must be applied and must not be removed, until all the work has been completed.

In general, high voltage circuits in buildings should be located where they will be inaccessible to steel mill mechanics, bricklayers, riggers, painters, etc. Outside circuits should be substantially constructed on towers high enough to clear locomotive cranes and when carried on buildings should have safe working clearance from the roof which should never be less than ten feet.

Group operated disconnecting switches that can be locked in or out of service are safety features that should be applied to new installations wherever possible. On old installations an interlocking of doors can be substituted to give the same protection. Modern truck type switching equipment has been developed to give everything desired in safety. The addition of doors, safety bars and locking features should be applied until the old installations are as safe as the new.

Regardless of the equipment, the keynote in safe high tension practices lies in following a definite routine.

DO NOT CLOSE

CIRCUIT Cable No. 107 **DATE** 4-7-28

ORDERED OFF BY John Doe **TIME** 8:00 A. M.

ORDERED ON BY John Doe **TIME** 12:00 Noon

REASON: Repairs to Feeder

.....

OPERATOR Jim Brown **SUB STATION No.** 1

When removed from Circuit Mail to Load Dispatcher

CAUTION

CIRCUIT Cable No. 107

ORDERED OFF BY John Doe

TIME 8:00 A. M.

REASON: Repairs to Feeder

Hold in sight for Relief Operator

*Anti-Friction Bearings for Auxiliaries in the Iron and Steel Industry**

By ERNEST S. JEFFERIES†

THE success which has crowned the efforts of the Steel Mill Industry in its adoption of Anti Friction Bearings in the large number of diversified units which make up Auxiliary Equipment has been very gratifying and has led to a more extensive program of fighting Friction. This development has been over a long period of time so that today the use of Anti Friction Bearings is the rule and not the exception. Equipment distributed through Coke Ovens, Blast Furnace Operation, Open Hearth Equipment, and the various types of Finishing Mills for producing different products are continually being improved in operation by the use of Anti Friction Bearings. When Anti Friction Bearings are applied to Auxiliary Equipment it generally necessitates a higher initial cost on the total equipment but this increased cost is but a very small percentage of the total, and the increased investment is amply returned in improved operation, considerable power saving, reduced maintenance charges and elimination of costly repairs and subsequent delays or shutdowns.

The field of Auxiliaries is so vast that it is almost impossible to try to enumerate the advantages of the various possible applications. The purpose of this paper is merely to review and set forth in a general way the most prominent applications.

In the Blast Furnace Departments Anti Friction Bearings are contributing to low upkeep and maintenance cost on hot metal cars, cinder ladle cars, ore scale cars, ore transfer cars, pig casting machines, skip hoists, skip cars, conveyors, and the various smaller machines and equipment found around each furnace. Most engineering concerns are adopting Anti Friction Bearings throughout their design as standard practice.

Around the Open Hearths Anti Friction Bearings are likewise adapted to transportation equipment, such as ingot cars, charging cars, slag box cars, etc., and in the various worm gear and miscellaneous machinery used in connection with valves, door lifts, and air reversing equipment.

The adoption of Anti Friction Bearings in transportation equipment has resulted in a considerable saving in power which in turn means that where double heading was necessary the same load can be taken care of by single locomotives. In all such transportation equipment the design of the journal box is such as to preclude the possibility of dirt, dust, scale, hot metal or other foreign matter getting into the bearing and the life therefore is increased considerably over the ordinary brasses. The danger of waste box bearings getting on fire is eliminated, actual breakage is reduced to a minimum and actual performance for the past 15 years indicates the only attention necessary is periodic lubrication. Tests with ore cars have shown that co-efficient of friction for a loaded car running on well oiled plain bearings in good condition amounted to .034 whereas the corresponding figure for a car running on roller bearings was only .0095 or 1/3 the power required.

Throughout Finishing Mills Anti Friction Bearings have been used on every type of mill table. Special note is to be made of the application of Anti Friction Bearings on the tilting tables for structural mills where maintenance is a big factor and where power saving is of importance. The application of Anti Friction Bearings to mill rolls requires consideration as it has been proved that the bearing friction with babbit bearing amounts to 50% of the total power consumption—a saving of 39% has been made in certain installations.

The manufacturers report that on one particular application the replacement of 17 brass bearings per week on a complete mill tilting table was common, but since changing to Anti Friction Bearings they have operated for five years and only replaced five roller bearings.

Blooming Mill Manipulators act quicker, with less power and maintenance when equipped with roller bearings and the same general statement applies to all other Auxiliary Equipment in and around the mills.

In all these mills and departments overhead cranes, both standard cranes, pig cranes, ladle cranes, etc., are used to handle material, and considerable progress has developed in recent years in equipping these cranes with Anti Friction Bearings. Many large cranes up to 275 tons capacity have recently been purchased and put into operation which have been equipped with Anti Friction Bearings throughout and the success which has attended these cranes is evidence enought that in the future the standard crane will be specified entirely with Anti Friction Bearings. Cranes so equipped give better service, with minimum power required for the bridge and trolley travel, smoother acceleration, and due to the decreased amount of repairs, upkeep and lubrication, a saving in maintenance attendance is brought about. The increased first cost is partly offset, by the application of motors and control of lower horsepower. As a comparison, with no load on a crane, a test was made on the bridge drive using Anti Friction Bearings. This test showed that the load to start was no greater than the load to run. A similar test, where plain bearings were used showed the load to start was 4½ times the load to run. As most peaks are due to starting this is an added benefit.

Coming now to the various types of gear drives. An ideal application for Anti Friction Bearings is on the pinion and gear shafts of the large mill gear reducing units. The high speed and possible unbalancing of large loads on units where flywheels are used can very effectively be handled by roller bearings with a complete elimination of prevalent bearing troubles. On the gear shaft, which must handle the

*To be presented at A. I. & S. E. E. Annual Convention June 25-28, 1928.

†Elec. Engr., The Steel Company of Canada, Ltd., Hamilton, Ont., Canada.

extremely large torque and excessive thrusts from the mill, Anti Friction Bearings because of their steady and carefree operation will pay for themselves in a very short time. Reducing Gears with Anti Friction Bearing applications are in service, the design of which allows the pinion shaft to float and locate itself in reference to the position of the gear which is fixed or vice versa.

Worm Reducing Gear Units are built with roller or ball bearings on both worm and gear shafts. The use of roller bearings with very large load carrying capacity permits of bearings of small outside diameter being used. This makes it possible to locate bearings close to the teeth of the work.

Small Reducing Units with Double Reduction Spur Gear Drives as well as Large Bevel Gear Drives have also successfully used Anti Friction Bearings in the same combination of bearings as used in the Helical Gear Units, that is, roller bearings to carry radial loads and a deep groove single ball bearing to sustain the end thrust.

The cost of maintenance of bearings on Hot and Cold Saws has always been very large. This is due to the high speed of operation and the extremely large shaft loads. Anti Friction Bearings have been successfully applied on a number of Saws and have practically completely eliminated these costs. Such Anti Friction Bearings are mounted on self-aligning boxes. The box adjacent to the Saw is positively located in the Pedestal and the bearings are fixed to the Spindle, thus locating the position of the Blade. The opposite box is located in the Pedestal but the bearings are permitted to float on the Spindle to take care of expansion. Such bearings are equipped with a continuous circulating oil system.

Ball and roller bearings are particularly applicable to motors and other high speed drills which operate in other than the horizontal position.

The standardization of the outside overall dimensions of ball bearings is a great advantage to their use as it permits the interchanging of various makes.

Where there is a possibility of misalignment, due to rough workmanship on the bearing supports, or, as in the case of line shafting, where the bearing supports are widely spaced, the application of Anti Friction Bearings of the self-aligning type or with self-aligning box provides that each bearing will carry its share of the load.

The author of this paper is indebted to Messrs. S. M. Weckstein, D. E. Batsole, J. M. Kelly, A. E. Kerr, for their assistance in submitting information and compiling data contained herein.

---

*Anti-Friction Bearings for Electric Motors**

By J. S. MURRAY‡

ANTI-FRICTION bearings of some type, as furnished in standard sizes by the well known manufacturers in this country, have been so generally adopted for steel mill motors in the last few years, and the subject has become one of such great importance, that this Association maintains a special committee as a clearing house for information on the subject for its members.

It is the desire of this committee at this convention to give a general outline of what the market affords in this line, the individual advantages of each type of bearing and its special adaptation, but feels unable to present this comprehensive subject in such a manner as to do justice to all, therefore we have asked several manufacturers of the outstanding types of anti-friction bearing to tell the Association, in their own words, what they make, and the advantages derived from the special form they have adopted.

At the present time the favors seem to be very equally divided among all types of these bearings, rollers, cones and balls, single or double row, etc., with the only point of agreement being on the general classification of anti-friction, so there should be ample ground for active discussion on the subject.

With this introduction the Committee submits the following papers which speak for themselves, feeling that with their grasp on this subject these writers will give our members a better understanding of the situation than any digest this committee could make:

ANTI-FRICTION BEARINGS—THEIR DESIGN AND USE IN ELECTRIC MOTORS†

The fundamental differences between anti-friction bearings and sleeve bearings require a thoughtful consideration on the part of both the manufacturer and the user of electric motors to determine which type of bearing is most suited for the particular application under consideration. There is no need in this paper to discuss the advantages and weaknesses of sleeve bearings since all of us are familiar with them. On the other hand, a discussion of anti-friction bearings is desirable as it is only within the past five years or since the activity of the Association of Iron & Steel Electrical Engineers, that the anti-friction bearing in steel mills has been used generally.

The ball or roller bearing is not a panacea for all bearing trouble. Properly selected and applied

*To be presented at A. I. & S. E. E. Annual Convention, June 25-28, 1928.

‡Elec. Engr., Follansbee Bros. Co., Follansbee, W. Va.

†Contributed by the S.K.F. Industries, Inc.

it offers a definite and tangible return on its investment. Improperly applied it will, except in rare cases, result in unsatisfactory service and high maintenance costs. The fundamentals of anti-friction bearing practice must be understood to obtain its most satisfactory performance.

In practically no industry do the special characteristics of anti-friction bearings lend themselves better than in the steel mill and on steel mill motors. In the first place all equipment must be capable of withstanding high overloads without any attendant weakening of parts. The anti-friction bearing has this ability to take excessive overloads without trouble. For example, a bearing capable of carrying a continuous load of five thousand pounds will carry momentary overloads of three or even four times this amount. This is possible since the load is taken by the elastic deformation of the steel balls or rollers in metal-to-metal contact with their races. On the other hand with the plain bearing the support of the load is taken on a film of lubricant interposed between the shaft and bearing surface. The physical properties of this film limit the allowable pressure which can be sustained without seizing. The attendant difficulties of maintenance are reduced. The summary of motor failures based on replies from steel mill engineers indicate that in alternating current motors 37% and in direct current motors 41% of all failures are directly attributable to motor oil leakage from plain bearings. Anti-friction bearings assure the user of complete absence of this trouble.

The most important single feature is that of reliability. There is probably no industry in which reliability is a greater asset than in the steel mill. The definite knowledge that the bearings in the motors will continue to operate without any shutdowns has more than anything else resulted in the present use of them. In such locations where formerly spare motors and armatures were standing by to replace those which failed the anti-friction bearing motor today stands alone and has proved its reliability. With the increasing use of remote control to start, stop or vary the speeds there must be the absolute certainty of proper functioning.

To insure reliable performance of anti-friction bearings, proper attention must be given to the following points:

(1) Type of bearing.
(2) Size of bearing.
(3) Method of application.
(4) Maintenance and lubrication.

(1) Type of Bearing:

Experience shows that no rule can be used to determine when any specific type of bearing should be used to the exclusion of all others. There is no sharp line of demarcation between those applications which are in the realm of ball bearings and those in which roller bearings are desirable. In general however the following is used as a basis:

	Speed Range	Load	Applications
(1) Deep Groove Ball Bearing	High	Medium Load with medium high thrust in either direction	Vertical Pumps, Fans, Motors with bevel gears, no misalignment
(2) Self-aligning Ball Bearing	High	Medium load with little thrust	General Purpose Motors. Misalignment
(3) Cylindrical Roller Brg.	Medium High	Medium High Load with no thrust	Roller Motors, Crane Motors. **No Misalignment**
(4) Spherical Bearing	Medium High	High load with high thrust in either direction	Steel Mill motors heavy duty applications. Misalignment

In general it is the spherical bearing that meets the requirements of heavy duty applications in the steel mill. It has the inherent property of self-alignment, is capable of high shock and radial loads, will carry thrust loads in either direction and is self-contained thus requiring no adjustment. In its frictional characteristics it compares favorably with the ball bearing.

(2) Size of Bearing:

With whatever type of bearing used, consideration must be given to its proper size. A knowledge on the part of the engineer as to the service requirements of the motor is necessary to determine these average load conditions. A slight increase in actual bearing capacity means a large increase in the life of the bearing. As an example let us consider a bearing carrying a load of 1,000 pounds. If we increase the capacity of the bearing selected by two we increase its life ten times. Similarly if we reduce the load to 500 pounds we increase the life by ten times. Thus it may be seen that a knowledge of the conditions of service are of utmost importance to insure suitable bearing size and through this proper bearing life. This phase was given complete study by the Iron & Steel Bearings Committee before their selection of recommended bearing sizes, both on general purpose and mill motors.

(3) Method of Application:

Shaft: Due to the comparatively small width of the anti-friction bearings the projected area between the bore of the inner race ring and the outside diameter of the shaft, leads to high values of pressure under usual operating loads. This pressure will amount to from 500 to 1000 pounds per square inch. This intensity of pressure requires a positive means for securing the two together to prevent relative rotation. If clearance exists between these parts

there will be a rotation similar to that of a spur gear meshing with an internal gear of slightly larger pitch diameter. This creeping under high pressures will develop destructive wear of shaft with heating. To overcome this, it is necessary to have a press fit of inner race on the shaft, and whenever possible secure the race against a shaft shoulder by an adequate locking device.

Housing fit: The outer race of the bearing is also of importance. As in the case of the inner race the unit pressures are high and to prevent localized stresses the bore must be uniformly round. The fit between the housing and outer race should be a comparatively free "sucking" since by using this fit the outer race is allowed to turn slowly subjecting the entire periphery to the load. In the usual mounting one bearing is held to stabilize the shaft, while the other is free to float axially. It may be that if both bearings are fixed, and machining inaccuracy or shaft expansion occurs both bearings will be subjected to high axial loads of indeterminate amount. By holding one, this possibility of trouble is avoided. The "sucking" fit of the bearing in the housing prevents any possibility of lateral binding in the free bearing.

Housing design: The bearing must be kept free from dirt. Various seals are used depending on the nature of the application. The felt grooves are generally used, and it is desirable to renew felts in this type of enclosure at infrequent intervals. Double or triple oil grooves provide another satisfactory method of sealing housings. Here close clearances between the shaft and housing further preclude dust entrance. Flingers and labyrinth enclosures in particularly dirty locations prove very effective. In general it is known that mechanical seals depending upon close clearances offer advantages in the steel mill since renewal of parts with this type is unnecessary.

Lubrication: Today there are few motors built which do not provide for ample lubrication space, to allow for enough grease or oil to insure operation over a long period of time without renewal. There is little wearing out of the lubricant since it has only two functions to perform. The first is to lubricate the parts of the retainer in contact with the balls or rollers and the second to keep the highly polished surfaces from corrosion. As a result only a small quantity of oil or grease is required, and consequently the lubrication problem is greatly reduced. Several manufacturers now make a neutral mineral lubricant which is desirable for anti-friction bearings. At intervals of from one to two years, the old grease or oil should be replaced with new lubricant. The only precautions which need be taken are that the lubricant be kept clean and that not too much is used.

So far we have dealt primarily with the bearing and its application to motors. In the last analysis it is the results that count. A few of these may be of interest.

On one mill, 4—125 HP reversing table roll motors have been in service for four years replacing motors with plain bearings. The records of the latter show 168 bearing failures per year or on an average of one every 9 days. No trouble has been experienced with the spherical bearings used in these motors.

On the traveler motor of an open hearth loading crane, plain bearing motors failed on an average of once a month due to heat and severe service conditions. The spherical bearings have been in operation for five years with perfect bearing performance.

On small man cooler fans, plain bearings due to oil leakage required continual attention. Failure of motors once a week was not uncommon. Ball Bearings were installed and no failures have occurred for three years and bearings are lubricated every six months.

In a large southern mill roller bearing motors used on the table rolls were recently examined after three years of operation. The actual wear in the rollers and races could not be measured since it was less than .00025". Sleeve bearings in the same location ran for less than six months.

Recently a prominent electrical superintendent had occasion to examine the gears on crane motors equipped with anti-friction bearings. The motors installed in 1916 have not been replaced, and the original tool marks in the gears are discernible.

A superintendent write as follows:

"In the last analysis, the absolute reliability of anti-friction bearing motors is one of their greatest advantages. When properly designed, they require practically no attention and the units may be stopped, started or the speed varied from remote points with absolute certainty of proper functioning."

The General Electrical Superintendent of one of the large Canadian companies states that the greatest benefit derived from anti-friction bearings in his motors is the "fact the lubrication is made much more reliable. There are no rings to jump off the shaft, and should the grease cup be broken from the housing the lubricant will not leak out. Also there are very few cases of rotors rubbing on stators."

A survey on five representative plants brings out the following:

Saving effected annually by use of anti-friction bearing Motors:

Lubrication		Maintenance and Repairs
Lubricant	Labor	
83.8%	74%	85%

The statements of the chief electrical engineers of one of the large steel mills probably covers the subject of anti-friction bearings fully.

"We feel that where their application has been carefully studied and the true economic significance placed on their performance, in relation to the entire machine or process, that anti-friction bearings have made a most creditable showing in our equipment."

ROLLER BEARINGS FOR ELECTRIC MOTORS*

During the past few years the question of applying anti-friction bearings to electric motors and other electrical apparatus has been kept pretty well before the Association of Iron and Steel Engineers through the activities of the membership and bearing manufacturers. Today there are very few steel plants in which these bearings are not in use in elec-

*Contributed by the Hyatt Roller Bearing Co.

trical equipment, and the satisfactory results obtained indicate that the future will see their universal adoption in most types of rotating electrical machines.

The advantages of anti-friction bearings for this equipment lies in their dependability, freedom from shut downs ordinarily attributable to bearing troubles, reduction of general maintenance, and freedom from attention for lubrication.

Roller bearings of the hollow helically wound roller type as made by our Bearing Company have been in service for a number of years in heavy duty motors operating under the most severe service found in steel plants and have reduced replacements and shut downs to practically a negligible figure.

One steel plant changed over its motors on the screw down drive of a 45" Blooming Mill from sleeve bearings to Roller Bearings. These motors were 75 HP size mill rating and the sleeve bearings required changing every month or so. To date the Roller Bearings have operated three years without change and with lubrication at intervals of three months.

Another plant changed over 39 HP series wound motors on rail mill tables which due to high speed required changes to sleeve bearings, weekly. Roller Bearings in these motors have operated two and one half years without change.

These and other examples of improved service due to roller bearings, have resulted in many of the steel plants adopting a program of changing over their existing sleeve bearing motors to roller bearings, and also to specifications to motor manufacturers to include roller bearings when purchasing new equipment.

Among some of the new motor installations equipped with Roller Bearings may be listed all motors for the Alloy Mill of the Illinois Steel Company at South Chicago, the 40" Blooming Mill of Jones and Laughlin, South Side Works, Pittsburgh, Pa., the National Tube Company's new Tube Mill at Lorain, Ohio, Bethlehem Steel Company's pipe mills at Sparrows Plant, Maryland; also motors for new cranes for Carnegie Steel Company, Ohio Works, National Tube Company, Lorain Works, Trumbull Steel Company, A. M. Byers Company, American Rolling Mills Company, etc.

Among the recent applications of Roller Bearings to large apparatus the motors for an ore bridge for one of the western plants might be mentioned. These motors are 275 HP. rating at 410 R.P.M., shaft extensions are 5½" and 6", and over-all dimensions, 7'7" long by 3'10-11/16" high. Also, it might be interesting to the members of the Association to know of a roller bearing, 4400 KW. rotary converter built by the General Electric Company and installed in a large eastern sub-station. This installation has been in service about one year.

It is a significant fact that electrical superintendents who have been applying roller bearings to their motors for as long as fifteen years are the strongest friends of these bearings and would not think of ever changing back to the old type of sleeve bearing.

Not only were the results obtained from the out set very satisfactory, but improvements in the bearings and the method of mounting as dictated by experience have insured a wide adoption of these bearings which will no doubt lead to complete standardization of these bearings on motors in the future.

ANTI-FRICTION BEARINGS FOR USE IN MOTORS*

One of the prime reasons for the almost universal trend to anti-friction is the various types of machines manufactured today is to take advantage of the possible power savings obtained. These savings have been found to be very gratifying in a large number of applications such as steel mill roll necks and auxiliary drives. Although there is a great deal of difference in opinion as to the amount of power that may be saved by anti-frictioning electric motors, the demand for motors equipped with either ball or roller bearings is becoming greater and greater every day. The reason for this is that there are a number of other advantages derived from the use of the anti-friction bearings which far overshadow the factor of power savings. These advantages may be put down as follows: (1) The motor air gap is maintained to factory fixed dimensions, because wear is reduced to a minimum by the elimination of sliding friction; (2) Cleaner stator windings, because the bearings can be effectively sealed; (3) Uses grease instead of oil and eliminates oil dripping from motors; (4) Reduces maintenance, since effectively sealed bearings using prease will require relubrication only after months of operation and will practically eliminate the repair bills; (5) Overall length of motor reduced, insuring more rigid construction; (6) Universal application, since motors will operate in vertical or horizontal position without additional devices to complicate the design. These advantages hold true in all motors of the general purpose induction and direct current type, mill motors and traction motors.

To keep up with the anti-friction development in motors the Timken Roller Bearing Company made an extensive study of the application of their bearing and after a number of years of experimentation in conjunction with a number of leading manufacturers of electric motors brought out a design for use on general purpose Induction Motors. The bearing cones, or inner races, are press fitted on the shaft to avoid creeping or peening out of the bearing seats. Bearing adjustment is obtained by means of shims or by means of a threaded end cap or a specially designed spring back of the cup, or outer race, on one end of the machine.

A very careful study was made of the axial expansion of various types of motors to determine the range over which the single bearing is applicable. It was found that the ordinary induction motors, due to the open construction, there was no appreciable difference in expansion between the shaft and motor frame under various condition of loading. The single bearing mounting therefore, meets all requirements and has performed very satisfactorily for a period of years in thousands of motors.

On direct current motors, however, it was found that there is a considerable difference in expansion between the motor frame and shaft and the single bearing mounting did not function satisfactorily under all conditions. This led us to a new develop-

*Contributed by the Timken Roller Bearing Co.

ment. In this design two single bearings were mounted with the cones back to back and the cups in cartridges. The bearings were adjusted in these cartridges by means of nuts securely locked to maintain the proper adjustment. Both cartridges were mounted in the end bells with a sucking fit and were permitted to float so as to take care of expansion. This worked out very satisfactorily but the additional catr of the cartridges made the proportion almost prohibitive from a commercial standpoint. Another serious objection was the increased diameter of the bearing cartridges and the consequent reduction in the ventilation characteristics of the motor.

These disadvantages and the increasing demand for roller bearings for motor use brought on the development of the Double Row Self Contained Timken Bearing. This bearing can be and has been very successfully incorporated in all types of direct current motors. It is recommended that the bearing on the extension end of the motor be fixed laterally while the bearing on the opposite end be permitted to float. This mounting will permit of taking care of the bearing thrust and radial loads close to their point of application and at the same time will compensate for any expansions which may occur. Outstanding advantages claimed for this type of mounting are: (1) Large bearing capacity built into motor; (2) Improved ventilation due to reduced outside diameter of bearings; (3) Efficient bearing closures reducing maintenance to a minimum; (4) Elimination of threading of shafts by providing a long seat on bearing and a press fit on shaft.

It will be interesting in this connection to note that the Double Row Bearings are being manufactured in all sizes from metric size 304 up to 330. These bearings are exactly interchangeable in bore, outside diameter and width with the medium serious double row ball bearings.

Since the Double Row Bearings have been placed on the market they have been adopted a standard by a number of manufacturers for use in general purpose motors, mine motors, mill motors and traction motors. Several hundred of these motors of various types and operating at various speeds are now out in the field and are giving a very good account of themselves. This is especially true of mill motors where the greatest progress has been made. The bearings are mounted in cartridges which in turn are located in the motor frame and locked against rotation by means of pins. The bearing in one of the cartridges is positively fixed, while in the opposite cartridge it is permitted to float to take care of expansion. The bearings are given a press fit in the shaft and are properly located by means of the spacers. Grease lubrication is provided for the cartridges are machined or cored with passages to permit the lubricant to circulate around the bearings. The annular groove closures shown in the illustration have proven themselves very effective for this service.

The selection of a suitable grease is very important especially for the higher speed applications. The most common greases on the market are compounded from a calcium bare soap. These greases melt at about 190 degrees Farenheit and once they become fluid they seldom return to the form of grease but separate into soap and oil. Greases compounded with a sodium base soap have a higher melting point and the decided advantage that they return to the form of grease on cooling from the fluid state. The grease should be compounded with an oil of not less than 200 seconds viscosity. Saybolt Universal at 100 degrees Farenheit. The consistency should not be too light or excessive churning will result.

ANTI-FRICTION BEARINGS FOR USE ON MOTORS*

In the consideration of electric motors for steel mill service, it is well to divide such motors into two classifications, namely, General Purpose or unit frame motors and Steel Mill or split frame motors. The problems involved in the mounting of ball and roller bearings are somewhat different for the two motors, although the fundamental principles are the same regardless of the type of motor.

While it is difficult to associate the idea of small fractional horsepower motors with steel mill operation where motors of unusually large size are commonly found, it nevertheless is true that the electrical department is frequently called upon to lubricate and repair motors of very small sizes. As examples, we have temperature recording and regulating motors, relays and other sensitive apparatus depending upon the successful operation of its bearings for reliable results. In this application small open type ball bearings are used with a spring adjustment to insure smooth and frictionless running.

Coming to larger motors for general purposes, we find many equipped with ball bearings of the closed type at each end of the armature. To avoid cramping of the bearings through shaft expansion and contraction, one bearing is clamped endways with respect to its outer ring while the other bearing is free to float.

Where there is a long overhang of the shaft beyond the bearing or where the load to be carried is large, it is the usual practice to mount a roller bearing at the drive end of the shaft with a ball bearing at the opposite end for thrust. This arrangement, obviously eliminates any difficulties due to expansion of the shaft as the rollers of the roller bearing may move laterally across the face of the outer ring.

On very large motors, subjected to heavy radial loading with comparatively light end thrust, a combination of two roller bearings, Case A, is employed. The roller bearing at the closed end of the motor is of the self-contained type, locating the armature endwise, while the drive end bearing is of the separable type. Some manufacturers prefer to use the self-contained roller bearing at each end of the shaft, in which case the drive end bearing is allowed to float endwise as in Case B.

A vertical motor where the problem of withstanding the weight of the rotor and of maintaining the lubricant in the upper bearing is involved. A roller bearing is installed at the upper and lower ends of the motor with a deep groove single row ball bearing at the lower end to carry the downward thrust. There is a clearance between the

*Contributed by Norma Hoffmann Bearings Corp.

outer ring of the ball bearing and its housing to insure that no radial load will be carried upon it. Under these conditions the thrust load is distributed equally over all of the balls.

The upper roller bearing is carried on a bushing which in turn is mounted upon the shaft. This allows of the use of a tube surrounding the shaft and extending upwardly so that an oil level may be maintained to a height even with the middle of the rollers. Oil tubes extending from the two housings may be connected to oil level indicators so that the oil level may be maintained as desired.

In steel mill motor's the bearings are mounted in cartridges which are clamped between the two halves of the split frame. The bearings are of the self-contained type, the mounting being the same at each end of the motor. A clearance is allowed at each side of the outer ring to permit of expansion and contraction of the shaft without cramping of the bearings. The inner rings are mounted on the shaft with a light shrink fit by heating with oil, and for some applications a shrink ring is also used as indicated.

Where helical pinions are used on the shafts, it is of course necessary to carry the thrust load on the bearings in addition to the radial load. Cylindrical roller bearings are not designed for the carrying of heavy thrust loads, and where such conditions are encountered a special mounting is used.

---

*The Selection of Main Drive Motors for Strip and Skelp Mills**

By A. F. KENYON†

A GREAT number of factors must be considered in selecting the proper motor drive for any proposed rolling mill. The capacity of the motor or motors is affected directly by the size of the billet and of the finished product, by the number of passes and the reduction in each, by the analysis and temperature of the steel, and by the average and maximum tonnage production rates. Even when the horse power capacities of the driving motors have been determined, there still remain decisions to be made regarding the number and arrangement of motors, whether they shall be connected to the mill by direct coupling or through reduction gearing, whether constant or adjustable speed is necessary, and if adjustable speed, whether A.C. or D.C. equipment is the more suitable.

The term "strip" covers the general class of thin flat products which are rolled in relatively long lengths. Hoop indicates the portion of the range of thickness from the thinnest up to about 13 gauge, and of width from about ⅜" up to about 8". Skelp is that specialized material which is used in the manufacture of welded pipe, and may range in dimensions from 1/16"x½" to ½"x50" or more. Strip, as the term is now generally used, covers that broad range of sizes up to 50" wide and in thickness from about 20 gauge up to ½". It is evident that this range of product sizes may be rolled in a great variety of mill types, from the simplest to the most elaborate.

Calculation of Power Requirements

Several methods of calculating the power demand of, and hence of selecting motors of the proper capacity for any proposed new mill, are in quite general use. Such methods make use of data obtained by tests on existing mills which are similar to the mill under consideration. The variation in calculation methods is therefore largely in the form in which the test data is tabulated and adapted to general use, rather than any fundamental difference in the calculation.

A method of calculation which is in extensive use was described in a paper read before the American Institute of Electrical Engineers in 1912 by Mr. Wilfred Sykes. This method assumes that during a pass there is "displaced" a volume of metal equal to the product of the length before the pass and the difference in area before and after the pass. From test data taken on some existing mill, the energy

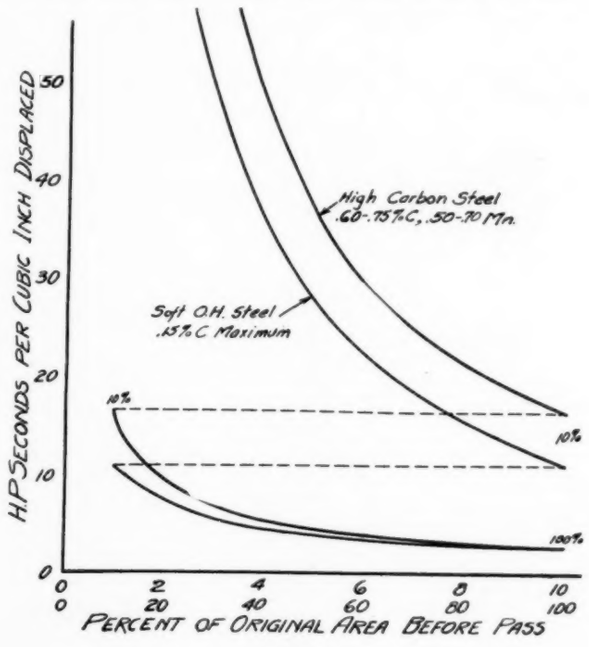


FIG. 1

*To be presented at A. I. & S. E. E. Annual Convention, June 25-28, 1928.

†General Engineer, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

consumption per unit volume displaced is calculated for each pass. These unit energy consumption values plotted with percentages of original area before the corresponding passes, result in curves of the general shape as shown by Figure I. The unit energy consumption is comparatively low at 100% original area before the first pass, but increases quite rapidly as the area become smaller, due to the decreasing temperature and increasing density of the steel. Table No. 1 indicates the method of using the data from

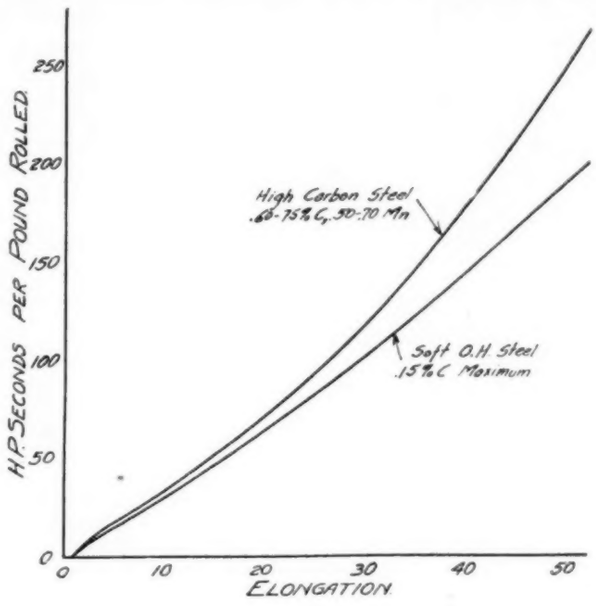


FIG. 2

one of the above curves to calculate the loads imposed by each stand of a similar mill. It is, of course, obvious that the shape and position of the energy consumption curve will be changed for other types of mills, for different analyses of steel, for different rolling temperatures, and may also be changed by heavier or lighter drafting, and by higher or lower rolling speeds. The data must be used only for calculations for rolling under similar conditions, or proper corrections made for any variable factor.

Another method of calculation of power requirements for individual passes of a mill is illustrated by Figure 2. The total cumulative energy consumption per unit volume or weight of the billet from pass to pass is plotted with the total cumulative elongation of the billet as the other co-ordinate. Figure 2 was

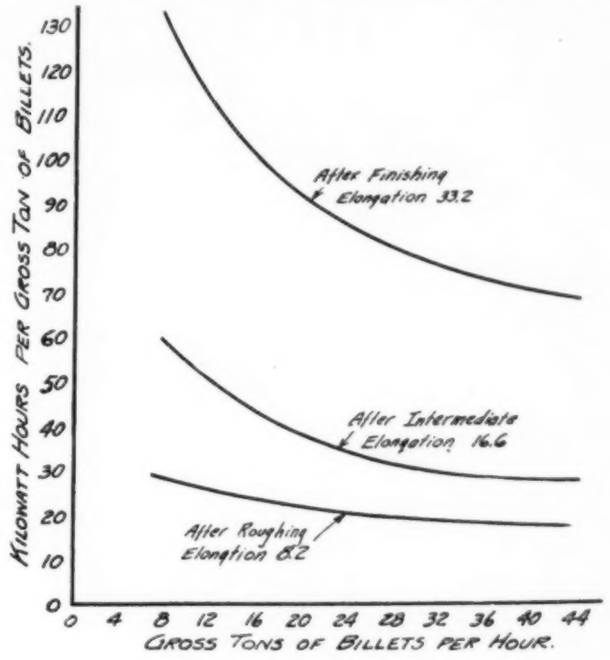


FIG. 3

plotted from the same test data as Figure 1. The unit energy consumption for any given pass is the difference between the cumulative energy consumption values at the corresponding elongations after and before the pass.

The calculations described above provide estimates of the power requirements of each individual stand of a proposed mill, and thus permit detailed

TABLE 1

POWER CALCULATION FOR ROLLING 16½ IN. BY 3 IN. BY 72 IN.—1010 LB. O. H. STEEL BILLETS TO 16 IN. BY 0.062 IN. STRIP

1	2	3	4	5	6	7	8	9	10	11	12	13	14
					4 x 5				5 ÷ 9		Fig. 1	6 x 12	13 ÷ 10
No. of pass	Section after pass, W. x T. in.	Area after pass, sq. in.	Difference sq. in.	Length before pas in.	Volume displaced cu. in.	Roll diam. in.	Roll r. p. m.	Roll Speed in. per sec.	Duration of pass seconds	% Area before pass	Hp-sec. cu. in. displaced	Net hp-sec.	Net rolling hp.
0	16.5x3.0	49.50											
1	16.0x3.0	48.00	1.50	72	108	13	35	23.8	3.10	100.0	2.7	292	94
2	16.2x2.0	32.40	15.60	74	1155	20	35	35.6	3.10	97.0	2.7	3,125	1010
3	16.4x1.0	16.40	16.00	110	1760	20	50	52.3	4.15	65.5	3.2	5,640	1355
4	16.0x1.0	16.00	0.40	217	87	13	95	64.6	3.45	33.2	5.0	435	126
5	16.1x0.625	10.5	5.95	223	1325	20	75	78.5	4.50	32.3	5.1	6,760	1500
6	16.0x0.625	10.00	0.05	354	18	18	53	49.8	7.15	20.3	7.4	133	19
7	16.0x0.312	5.00	5.00	356	1780	20	95	99.5	7.15	20.2	7.4	13,180	1840
8	16.0x0.210	3.36	1.64	712	1165	16	82	68.7	15.40	10.1	11.0	12,800	835
9	16.0x0.145	2.32	1.04	1059	1100	16	119	99.5	15.40	6.78	19.0	20,900	1360
10	16.0x0.109	1.75	0.57	1535	875	16	157	132	15.40	4.68	29.4	25,700	1670
11	16.0x0.083	1.33	0.42	2035	855	16	208	174	15.40	3.54	40.4	34,500	2240
12	16.0x0.070	1.12	0.21	2680	562	16	246	206	15.40	2.69	53.0	29,800	1940
13	16.0x0.062	.99	.13	3180	414	16	286	240	15.40	2.26	63.0	26,000	1690
				3700						2.00			
												179.285	

analysis of the load cycle. With additions for mill friction, and proper combinations of individual pass loads, the average and peak load conditions for any arrangement of the driving motors may be quite accurately determined, and motors to meet these conditions selected.

In addition to the above detailed calculations, it is often desired to check the total average power requirements and to estimate the total overall energy consumption. Such estimates are often made from KWH/ton-Elongation curves plotted from watthour meter reading on different schedules over considerable periods. In this connection it should be noted that, due to the idling friction load, the average tonnage rate during the test period may have a very considerable effect on the gross energy consumption.

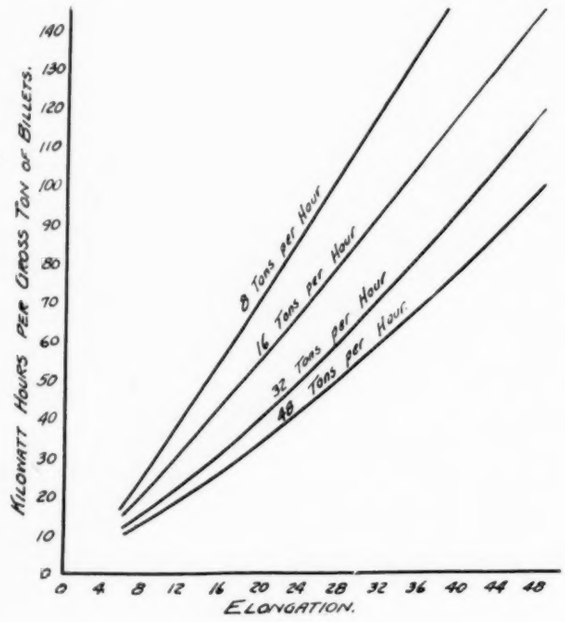
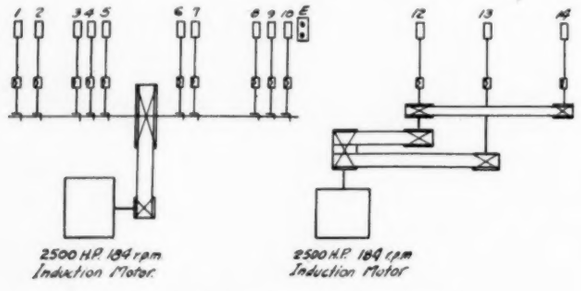


FIG. 4



13" Continuous Skelp Mill.

FIG. 5

The magnitude of the change in gross energy consumption is shown very clearly by Figures 3 and 4. The three curves of Figure 3 show the kilowatt-hour per ton energy consumption of the roughing, roughing and intermediate, and roughing, intermedite and finishing stands, respectively, of a 16" strip mill when rolling 12 gauge strip, and indicate the great increase in energy consumption at low tonnage rates. At 10 tons per hour the total unit energy consumption is seen to be about 70% greater than at 40 tons per hour. The curves on Figure 3 were plotted from data taken over an extended period of rolling on one particular schedule. Data from this and other similar curves for other rolling schedules were used to plot the curves on Figure 4, which shows kilowatt hours per ton—elongation curves for four different tonnage rates. The roughing and intermediate stands of this mill are driven by induction motors and the four finishing stands are driven by D.C. motors supplied with power from motor generator sets. The friction load is, therefore, higher than would be the case if all A.C. drives were used.

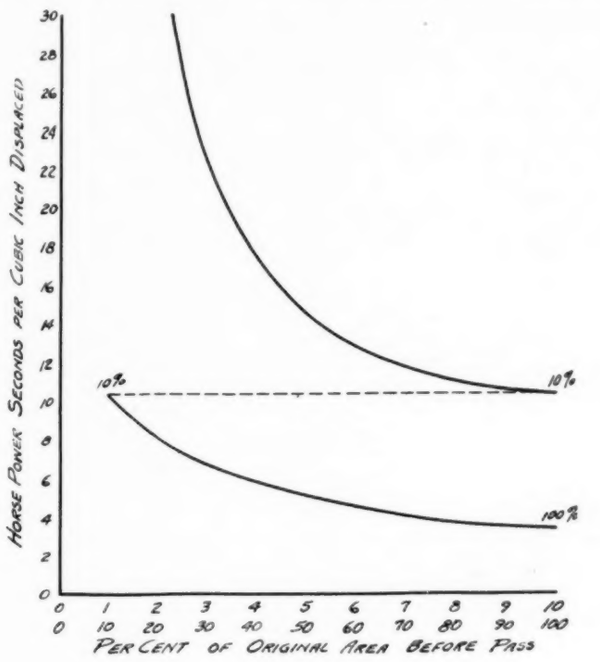
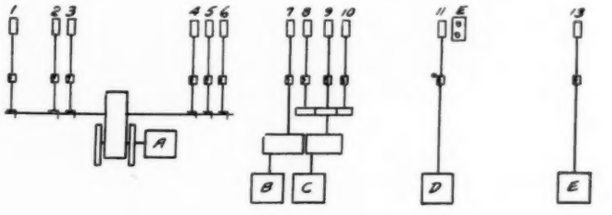


FIG. 6



14" Continuous Skelp Mill

Motor A - 1500 H.P. 491 r.p.m.
Motor B 1000 H.P. 293 r.p.m.
Motor C - 2000 H.P. 294 r.p.m.
Motor D - 1000 H.P. 209 r.p.m.
Motor E 1250 H.P. 294 r.p.m.

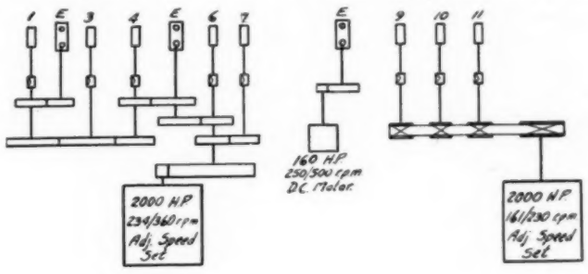
FIG. 7

As a final check on any detailed calculation, it is well to compare the motor sizes selected with those on similar mills which are known to be operating successfully on the same or comparable rolling schedules and under similar conditions. For instance, if a certain mill is known to be rolling 10" wide by 16 gauge strip from 3" thick slabs at a delivery speed

of 1200 feet per minute, and that the 6000 H.P. of driving motors are only comfortably loaded, it lends a degree of assurance to have a detailed study of a similar mill proposed to roll the same schedule at 1000 feet per minute result in the selection of motors totaling 5000 H.P.

Skelp Mills

The tolerances to which skelp must be rolled are usually not so close and the gauge for a given width is usually heavier than for other strip, so that most



10" Continuous Skelp Mill

FIG. 8

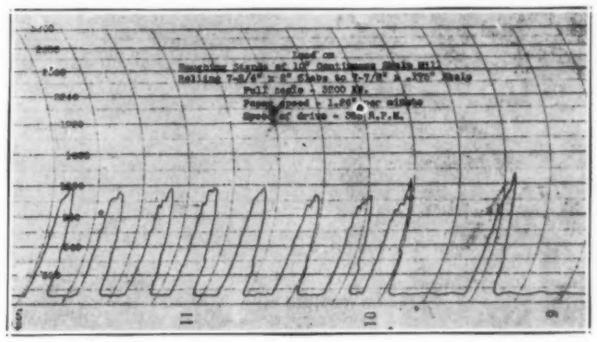


FIG. 9.

skelp mills do not require the refinements of arrangement which are so necessary to the successful operation of a strip mill.

For small and medium tonnage production of the smaller sizes, a simple mill train, or a looping finishing train with a separately driven roughing stand, serves very well. The operation of such a mill is too familiar to require further discussion. Wide skelp is produced in much the same manner and on the same types of mills as plate. This paper must confine itself to the discussion of mills which are designed for the specialized production of the medium sizes of skelp.

The 13" continuous skelp mill shown by Figure 5 is laid out to roll skelp in sizes ranging from 1 3/16" wide x .067" to .115" thick, up to 7¾" wide x.160" to .225" thick, at a delivery speed from the last stand of about 1150 feet per minute. The ten roughing stands are arranged in four groups, the groups being so spaced that the same piece is never in more than one group of stands at any one time,

TABLE 2

PARTIAL LIST OF MAIN ROLL MOTORS ON SKELP MILLS

No. Company	Location	Mill	H. P.	R.P.M.	Volts	Cycles	Type of Drive
1 Bethlehem Steel Co.	Sparrows Point, Md.	12" Continuous Skelp	1800	275/550	600	D.C.	Geared
			1800	275/550	600	D.C.	Geared
			1100	214/320	600	D.C.	Direct
			1100	240/382	600	D.C.	Direct
2 Bethlehem Steel Co.	Sparrows Point, Md.	27"-21" Sheet, Bar & Skelp	6500	187.5	6600	25	Geared
			4000	83.3	6600	25	Direct
			6700/3320	500/250	6600	25	Geared
			2600	275/320	600	D.C.	Direct
3 Gary Tube Co.	Gary, Indiana	14" Continuous Skelp	1500	491	6600	25	Geared
			1000	293	6600	25	Geared
			2000	294	6600	25	Geared
			1000	209	6600	25	Direct
			1250	294	6600	25	Direct
4 Gary Tube Co.	Gary, Indiana	16" Continuous Skelp	350	500	230	D.C.	Geared
			5500	370	6600	25	Geared
			2500	295	6600	25	Geared
			2500	146	6600	25	Direct
			3000	184	6600	25	Direct
5 Jones & Laughlin Steel Co.	Woodlawn, Pa.	10" Skelp	2300/1300	115/65	6600	25	Geared
			2090	250/161	6600	25	Geared
6 National Tube Co.	Lorain, Ohio	13" Continuous Skelp	2500	184	6600	25	Rope
			2500	184	6600	25	Rope
7 Wheeling Steel Corp.	Benwood, W. Va.	14"-12" Skelp	500	180/360	600	D.C.	Geared
			2000	200/400	600	D.C.	Geared
			2000	200/400	600	D.C.	Geared
			2000	200/400	600	D.C.	Geared
8 Youngstown Sheet & Tube Co.	Indiana Harbor, Ind.	10" Continuous Skelp	2000	350/234	2200	60	Geared
			2000	234/161	2200	60	Belted
9 Youngstown Sheet & Tube Co.	Indiana Harbor, Ind.	21" Sheet, Bar & Skelp	3600/1940	300/156	2200	60	Geared
			7500/4040	257/134	2200	60	Geared
			2000	85/165	600	D.C.	Direct
			2000	85/165	600	D.C.	Direct
			2000	85/165	600	D.C.	Direct
10 Youngstown Sheet & Tube Co.	Indiana Harbor, Ind.	42" Universal Skelp	2100	50/120	600	D.C.	Direct
11 Youngstown Sheet & Tube Co.	Youngstown, Ohio	30" Universal Skelp	4000	80/135	650	D.C.	Direct
12 Gary Tube Co.	Gary, Indiana	42" Universal Skelp	4500	120/255	750	D.C.	Direct
13 Tyler Tube & Pipe Co.	Washington, Pa.	16" Skelp	550	575	2200	60	Geared
14 Bethlehem Steel Co.	Coatesville, Pa.	22" Skelp	1500	277	2200	60	Geared
15 Elyria Iron & Steel Co.	Elyria, Ohio	16" Skelp	1000	600	2200	60	Geared

although it may be in the two or three stands of each group. The finishing stands are also spaced so that the pieces run out before entering the succeeding stands. The mill is driven by two duplicate 2500 HP, 184 r.p.m. induction motors through rope drives. Figures 6 is a composite average energy consumption curve for rolling 4"x5" billets to 3¼"x.113" skelp, and 3⅞" square billets to 2⅛" x .094" skelp.

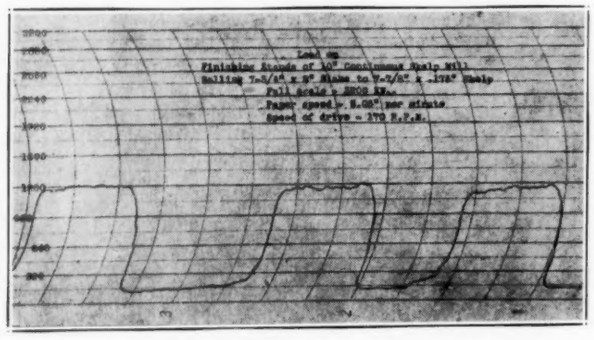


FIG. 10.

With the more recent installations, gear drives rather than rope are generally used, and there is also the tendency to apply a greater number of motors in order to lessen the complications of the gearing. Figure 7 is an example of a 14" continuous mill, designed to do practically the same work as the mill

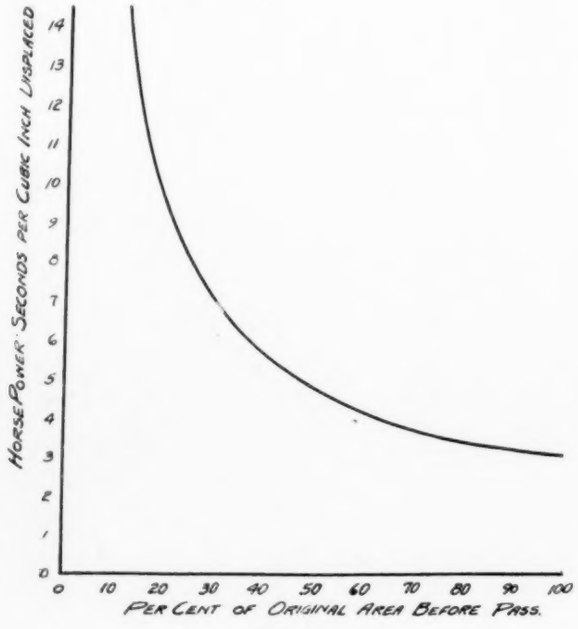


FIG. 11

just described, and with a very similar arrangement of the roll stands. With the greater number of driving motors, the diversity of load from the several stands is not so great, and a greater total H.P. of motors is necessary than if the mill were driven by one or two large motors. It is noted that the total H.P. of motors on the mill shown in Figure 7 is 6750 as compared to 5000 on the mill shown in Figure 5.

In other forms of skelp mills, the stands are all closely spaced in a continuous line, so that a single billet may be in all stands simultaneously. Such mills are very compact in their arrangement, require very little labor to operate, and finish the rolling at a fairly high temperature so that the energy consumption for a given rolling schedule is usually less

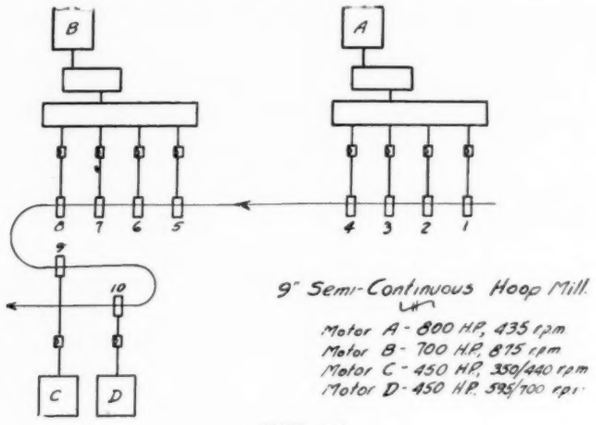


FIG. 12

than for a mill where the steel runs out between passes. The 10" mill shown in Figure 8 is so laid out. The seven roughing stands are driven by a 2000 H.P. 234/360 r.p.m. rotary converter type adjustable speed set, the edger is separately driven by a small D.C. motor, and the three finishing stands are driven through belt by a second 2000 H.P. adjustable speed set. The maximum delivery speed is approximately 1100 feet per minute. Figures 9 and 10 are sections of graphic wattmeter charts on the roughing and finishing drives, respectively, taken while rolling 7¾"x3" billets to 7⅞"x.175" skelp at a delivery speed of about 765 feet per minute. It is to be noted that the time scale is different on the two charts and that the duration of the peak load is

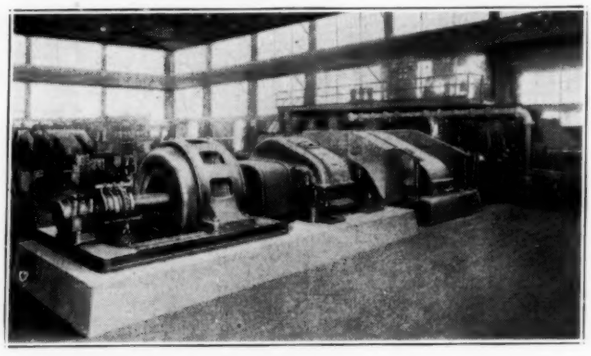
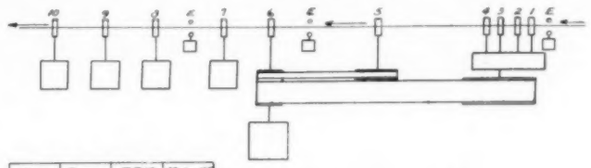


FIG. 13.

approximately the same for the roughing mill as for the finishing mill.

From data secured during the rolling of the 7⅞" x .175" skelp schedule, the energy consumption curve shown in Figure 11 was plotted. In comparing this curve with that of Figure 6, it is noted that the unit energy consumption at the beginning of rolling is approximately the same or slightly lower, but that the curves cross at about 35% area and from

that point on the curve on Figure 11 is the higher. At first thought, you would expect the curve for the compactly arranged continuous mill to be lower than for the mill in which the steel runs out between passes. However, Figure 6 is for rolling 4" thick billets to skelp which is only about 60% of the width of the billet, while Figure 11 is for rolling 2" thick billets to skelp of the same width as the billets.



Pass	Diam.	R.P.M.	Motor H.P.
Edger	—	675/825	100
1	12	31/63	—
2	12	45/90	—
3	12	61/122	—
4	12	90/181	—
5	11	123/249	—
Edger	—	400/1600	35
6	10	198/400	1500
7	10	185/470	600
Edger	—	400/1600	35
8	10	270/635	600
9	10	393/825	1120
10	10	480/1000	720

10" Tandem Hot Strip Mill

FIG. 14.

Thus at the same percentage of original area the piece in Figure 11 is only about a third as thick as in Figure 6. Thus can be explained the higher unit energy consumption of the mill shown on Figure 8.

Two of the most recently installed skelp mills are entirely driven by direct current adjustable speed motors. Adjustable speed drives are almost a necessity for a mill rolling any great range of product sizes, and where the motors are of small or medium size and closely grouped together, direct current often works out to advantage. On two other large

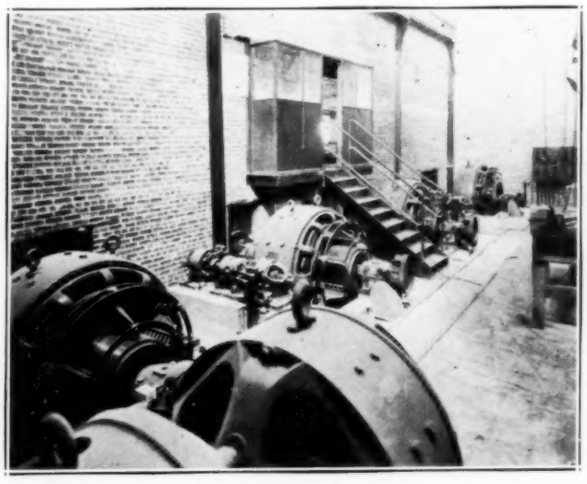


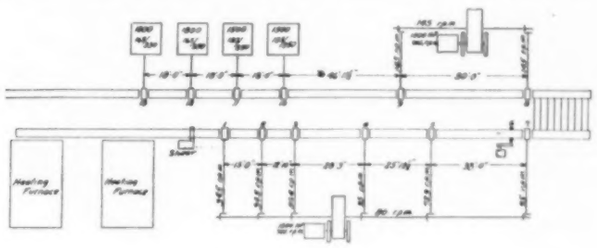
FIG. 15.

sheet bar and skelp mills the greatest economy in first cost and efficiency in operation were realized by a combination of alternating current drives on the roughing and intermediate sections and direct current drives on the finishing stands where the maximum flexibility and ease of control are desired.

Table 2 is a partial list of motor drives which have been applied to American skelp mills, and serves to indicate the size and type of drives for different forms of mills.

Hoop and Small Strip Mills

As has been previously mentioned, hoop is merely that part of the general class of strip products up to about 8" wide. This narrow material can be produced in very simple mills, but plants which specialize in its production often have mills especially arranged for the economical rolling of this light material. Certain mills operate almost entirely on cot-



West Leechburg Steel Co
20-16" Tandem Hot Strip Mill

FIG. 16.

ton ties, and such mills are designed for the rolling of this one product.

Figure 12 is an example of a small mill for the production of cotton ties and small hoop up to about 2" wide. The roughing and intermediate sections are driven by constant speed induction motors and the two finishing stands are individually driven by constant torque Kraemer type adjustable speed sets. Experience indicated that certain light schedules could be better rolled at higher delivery speeds than originally arranged for, and the necessary changes were made in the control to permit the operation of the finishing drives above synchronism. Operation is stable at speeds more than about 10% above syn-

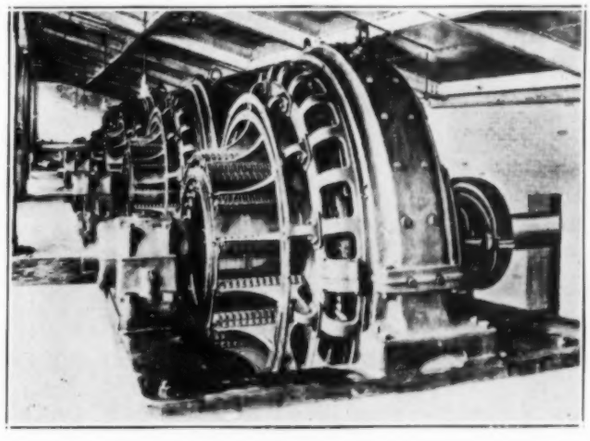


FIG. 17.

chronism and the sets are regularly so operated on certain schedules. Figure 13 is a view of the intermediate section of this mill.

A straight continuous mill for the production of strip up to about 8" wide is shown by Figure 14. The first six stands are driven by a 1500 HP D.C. motor and the four finishing stands are driven by individual direct current motors. The last five stands are of the four-high arrangement, with the backing rolls carried in roller bearings. On narrow thin ma-

terial the mill delivers at speeds up to 2600 feet per minute. The two 600 HP and two 720 HP motors driving the finishing stands are shown by Figure 15.

Large Strip Mills

The active demand for long lengths of 16 gauge and lighter material up to widths of 16" or more, by the automotive, metal furniture, and other industries has caused the installation in recent years of a large number of mills which are especially designed to produce this wide, thin gauge strip. The thin strip cools very rapidly, and thus to expedite rolling and enable the finishing of the process at a sufficiently high temperature, the stands are closely spaced in tandem, and the material rolled at comparatively high speeds.

The arrangement of the stands and driving motors of one of the earliest of these modern mills, installed in 1923, is shown in Figure 16. This mill is of the semi-continuous type, the steel being transferred broadside after the roughing passes and passed through the intermediate and finishing stands in the opposite direction from that traversed through the roughing mill. The roughing and intermediate stands are driven by constant speed motors and the four tandem finishing stands by individual direct current motors. Figure 17 is a view of the four finishing stand motors.

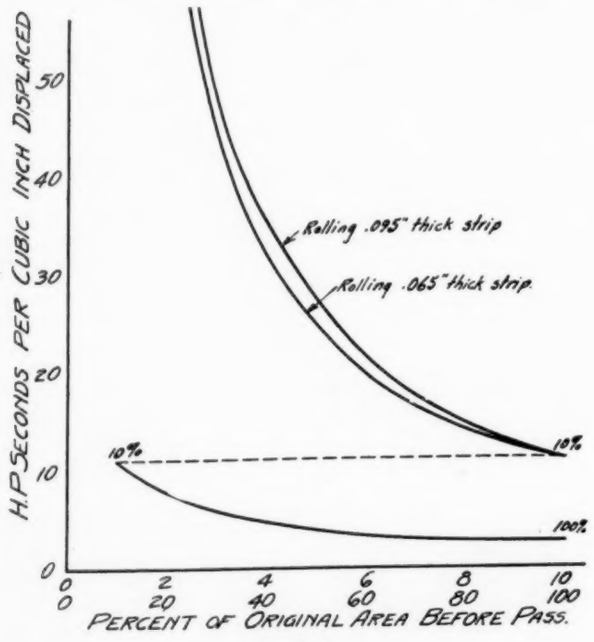


FIG. 18.

Energy consumption curves for rolling 3" thick billets to strip of various thicknesses are shown on Figures 1 and 2. On both figures the lower curves are for rolling soft steel with a maximum of .15% carbon, while the upper curves are for rolling high carbon steel, with .60-.75% carbon and .50-.70% manganese.

Reference has been made to the fact that variations in drafting the steel may affect the unit energy consumption for apparently similar work. As an instance of this, Figure 18 shows two curves, one for rolling 16 gauge and the other for rolling 13 gauge strip, and it is seen that the energy consumption is slightly higher for the heavier material.

This higher unit energy consumption for rolling the heavier material may be largely accounted for by the lower temperature at any given thickness when rolling the heavier material. For instance, if the 13 gauge strip is finished in the 13th pass, its temperature from Figure 19 will be approximately 1585° F. However, when rolling 16 gauge material in 13 passes, the strip will be reduced to approximately 13 gauge after the 11th pass, and from the curve its temperature at that time will be about 1680°F, or 95°F hotter. From such an analysis it would seem desirable to finish the rolling in as few passes as necessary to properly work the steel.

Roller Bearing Mills

The latest development in the rolling of thin flat products is the use of four high mills with the backing rolls supported by roller bearings. Such mills make possible the rolling of the thin gauges up to widths of 48" or more, and in lengths of several hundred feet.

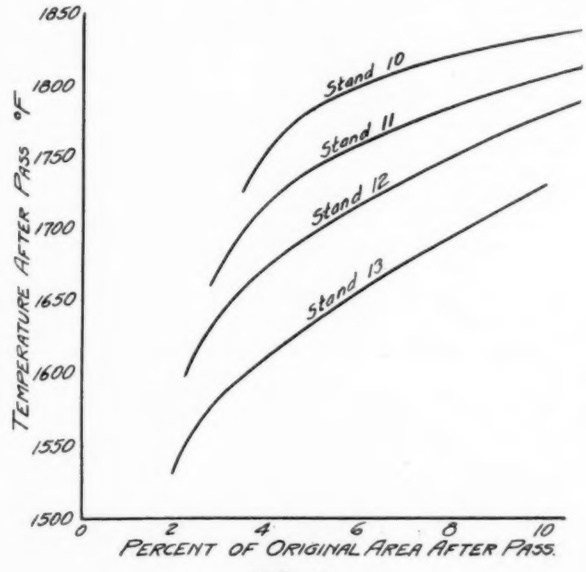


FIG. 19.

The roll neck friction in such mills is very much lower than in mills with plain bearings, and a very marked reduction in power requirements and energy consumption is to be expected. For instance, several strip mills rolling 16" to 20" wide 16 gauge strip at delivery speeds of about 1200 feet per minute, have 1800 H.P. motors on the finishing stands, and these motors are at times operated above their ratings. Modern mills with roller bearings, rolling 30" to 36" wide 16 gauge strip at delivery speeds of about 800 feet per minute impose loads on the finishing stand motors of about 1500 HP, indicating a saving in power requirements of about 40%. On some mills roller bearings are used on the roughing as well as the finishing stands, but it should be noted that the greatest savings in energy consumption are to be made on the finishing stands, where the rolling pressures are very high. The upper curve on Figure 20 is plotted from data from one of the 16" strip mills with plain bearings rolling 16 gauge strip from 3"

thick slabs, and the lower curve is plotted from data from one of the new mills having roller bearings on the finishing stands. The saving in energy consumption is very apparent as the elongation increases and rolling pressures become greater.

Motor Drives

This paper is largely devoted to methods of selecting the capacities of driving motors, rather than

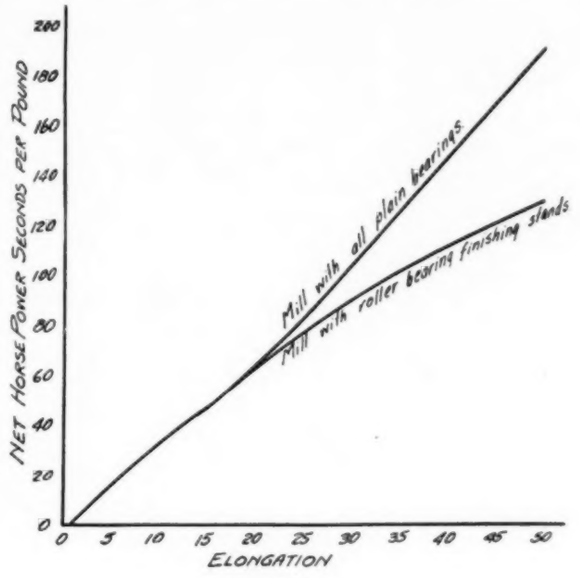


FIG. 20.

to the selection of any particular type of motor, as it is felt that the selection of the proper type is influenced by special conditions peculiar to each application. Some mills do not require adjustable speed, particularly on the roughing stands, and induction or synchronous motors may be used to advantage. On the finishing stands, adjustable speed is usually required, and either direct current or some type of alternating current adjustable speed drives may be used. The decision as to which to use must be decided after careful study of individual case, and no general rules can be laid down.

REFERENCES

1. Power Requirements of Rolling Mills, by Wilfred Sykes, A.I.E.E. Transactions, 1912, Volume XXXI, Part II, pp 2051-2066.
2. A New 20"-16" Hot Strip Mill, by Noble Jones and G. P. Wilson, A.I.E.E. Journal, August, 1924, pp 710-715.
3. The Electrical Control for a Hot Strip Mill, by M. J. Wohlgemuth, Electric Journal, September, 1923, pp 322-325.
4. Electric Drive for 10" Strip Mill at Laclede Steel Company, by A. F. Kenyon, Electric Journal, June, 1927, pp 312-317.
5. The Application of Direct Current Motors to Main Roll Drives, by H. A. Winne, Iron and Steel Engineer, April, 1927, pp 194-202.
6. Adjustable Speed Drives for Rolling Mills, by L. A. Umansky, Iron and Steel Engineer, September, 1924, pp 515-532.
7. The Application of Adjustable Speed Main Drives in the Steel Mill, by Gordon Fox and Arthur J. Whitcomb, Electric Journal, September, 1920, pp 367-371.
8. The Evolution of the Wide Strip Mill, by Stephen Badlam, American Iron and Steel Institute, October 28, 1927.
9. The Drive of Tandem Rolling Mills, by A. F. Kenyon, A.I.E.E. Regional Meeting, St. Louis, March 7, 1928.
10. Strip Steel and Mills for its Production, by Noble Jones, Iron and Steel Engineer, April, 1926, pp 155-163.

*Rules and Regulations Pertaining to Operation of a Steel Plant High Tension System**

By R. M. HUSSEY†

THE writer has been asked to give a brief outline of rules and regulations which are used in operating the high tension power system of a typical steel plant.

There are many rules which should apply to all electric power systems in general, but many other rules and regulations would necessarily apply to specific installations; to meet the peculiarities of those installations. Some rules which have been developed to meet a peculiar condition here would not apply in any way at some other plant.

Before operating conditions, and the rules pertaining thereto, are described, it would undoubtedly be well to describe the electric power system involved.

Two (2) 6600-volt, 25-cycle power plants, one at each end of the steel plant, are connected by four (4) circuits, two (2) being used as trunk lines and two (2) as sub-station feeder circuits; the sub-station feeder circuits being arranged in such a way that they can be used either as trunk lines, with taps taken off at various points for sub-stations, or sectionalized and used as radial type feeders from either power house. Three (3) sub-stations are fed from these two (2) through feeder-circuits, with taps from each circuit to each station, and two (2) other sub-stations have single taps off one or the other of the two feeder-circuits. All other sub-stations and motor rooms are fed over radial type feeders from one power house or the other, as the case may be, the

*To be presented at A. I. & S. E. E. Annual Convention, June 25-28, 1928.

†Elec. Supt., Jones & Laughlin Steel Corp., Woodlawn, Pa.

majority of motor rooms and sub-stations having two (2) feeders each, while others have only one radial type feeder serving them.

Rules for safe operation of the power system appear first in the engineering departments. It has been a rule for several years that line disconnects shall be gang-operated and equipped with locks arranged in such a way that oil switches feeding power through the disconnects must be opened and locked open before the corresponding disconnect can be unlocked and opened. This arrangement prevents a disconnect being opened while power can flow through it and, therefore, makes for safe operation when switching and clearing circuits for repair work.

Another rule which is applied in the engineering department and is intended for safer operation of the power systems pertains to sub-station, motor room, and power house design. There must be at least two (2) ways of exit from all such buildings and rooms that will permit operators, attendants, or repairmen to flee, one way or another in case of switch failures or other dangerous conditions. Designs showing "blind alleys" between switch groups or bus structures or rooms with only one door are not tolerated; both ends of alleys and passageways must be open and free for exit and all motor rooms and buildings housing electrical equipment must have at least two exits arranged so that a person can not be trapped.

Still another rule which designing engineers must follow is proper clearance of overhead lines above roofs for protection of riggers, painters, and other tradesmen, and over railroad tracks for the protection of train crews on box cars.

The operating board in each power house is adjacent to an oil-switch group and it seemed that the oil switches were a hazard to the operators. Consequently, strong walls were put in place between the operating boards and the switch groups so as to confine switch failure troubles and protect the operators.

The rules and regulations covering high-tension power system operations are as few and simple as possible, yet consistent with Safety First.

The switching of all circuits under normal conditions is directed by one man called Powerhouse Foreman. He is responsible for the proper switching of all 6600-volt circuits and directs the sub-station, motor room, and power house attendants in such work.

After the Powerhouse Foreman has completed the necessary switching work, he advises the Line Gang Foreman of all circuit conditions and names the circuits that are clear and safe to work on.

The Line Gang Foreman then becomes responsible in the matter of testing each circuit with an S. & C. voltage detector and chaining each circuit on each side of the place at which repairs will be made.

During line repair work all line disconnects, connected to any part of the circuits involved, are kept locked-open and a sign is hung at each disconnecting switch installation. This regulation is carried out by the operators in the various sub-stations and motor rooms, under the instructions of the Powerhouse Foreman.

The Line Gang Foreman checks the Powerhouse Foreman on circuit conditions as a precautionary measure by calling both power house operators and asking them to describe their circuit conditions and also by checking certain interconnections at various sub-stations and motor rooms.

After repair work on the circuits involved has been completed, the Line Gang Foreman orders all chains removed and, after having removed whatever padlocks he may have had put on disconnecting switches on interconnecting lines remote from the two power houses, he notifies the Power House Foreman that the Line Gang is clear and circuits may be put back into service.

The Powerhouse Foreman immediately tests each phase of all circuits, involved in repair work, to ground and between phases by using a megger. We have established certain resistance values as indicated by meggers that are based on past performance over a considerable period of time above which circuits should meg before they are again put in operation.

After such testing work by Powerhouse Foreman and providing megger indications seem satisfactory, circuit switching operations are completed and a normal operating condition is accomplished.

Whenever trouble occurs in any of the sub-stations or motor rooms, the attendants there must open all disconnecting switches involved, lock same open and stand-by for instructions from Powerhouse Foreman.

All linemen must work in pairs or in groups; one man alone is not permitted to work on 6600-volt circuits or equipment.

Although many sub-stations and motor rooms are each served by two (2) radial type feeders, only one feeder is used at a time; the two feeders are in parallel only during that time it takes to change from one circuit to the other. In one case, the motors must be shut down in order that the load may be changed from one circuit to the other. Operations involving only one radial feeder to each sub-station or motor room and no parallel circuits, keep short-circuit and other trouble currents at a minimum and within the range of oil switch capacities and, therefore, make possible safer operating conditions.

We have a 22,000-volt, 60 cycle connection with a central station system, for a bank of transformers at one of the rolling mills. Two (2) 22,000-volt circuits meet in a small switching station to form a loop. Both lines are equipped with oil circuit-breakers and gang operated disconnects on either side the breakers. We are concerned with the control of these switches to protect our transformers, the central station people must also have control for operating the loop relays, therefore, the gang operated disconnects are so arranged that both central station men and our own men may open the switches and lock same open with as many padlocks as there are crews of men involved.

During construction work or other work necessitating the relocating of transmission lines or taking a line out of service for days at a time, temporary circuit conditions are set-up. In order that power house operators may be kept completely informed as to temporary and unusual circuit conditions, blueprints of the transmission system are marked in red to indicate such conditions and are posted in the

power houses. As conditions change, blueprints are revised and new ones posted.

Doors in all unattended stations and motor rooms are kept locked and the keys are in the hands of responsible men, with the master key in the hands of Superintendent and Assistant Superintendents.

All ladders giving access to towers and platforms are equipped with doors securely locked so that no one can climb the ladders without first unlocking the door.

Porcelain enameled signs, warning of various conditions, are displayed wherever necessity demands, and all switches, gang-operated disconnects, and circuits are numbered.

In a large steel plant with overhead line construction, the Electrical Department is usually concerned with the operation of locomotive cranes. A rule is rigidly inforced here that makes it necessary for a representative of the Electrical Department to actually ride a locomotive crane when it is at work within boom-length of overhead lines. The cranes must also be operated with booms lowered as low as possible when traveling from place to place.

The few rules and regulations as they would appear when recapitulated as such, instead of described at length as above; the responsibility of creating safe working conditions being vested in no more than two men. Powerhouse Foreman and Line Gang Foreman; the personal checking for safety that may be done by reason of the comparatively short, compact system we have; together with adequate disconnecting switch installations and the methods used in interlocking same with oil switches; the building, sub-station, and motor room designs, permitting of ready exit in case of trouble; and the revamping of all 6600-volt switching equipment to provide oil switches of rupturing capacities capable of meeting all short-circuit conditions as calculated from short-circuit-table tests; all make for safer operating and maintenance conditions and continuity of service and seem to meet conditions peculiar at this plant in a satisfactory manner.

With all the rules and regulations that may be set-up and all the protection work done that can be done, there remains the man who may disregard rules and become shocked. In order to better cope with such an accident, the majority of the electrical men have been instructed in the prone method of resuscitation and demonstrations and practice periods for such means of restoring life have been arranged for at frequent intervals.

We realize that many things we de here may not apply to longer transmission systems, or to other plants, but this description applies to only one typical steel plant and not to any central station system.

---

*The Insulation of Open-Hearth Furnace Regenerators**

By L. B. McMILLAN†

Introduction

ONE of the outstanding improvements of recent years in the design and operation of open-hearth furnaces has been the application of insulation to the regenerator checker chambers. The magnitude of the radiation losses from open-hearth furnaces has long been recognized, but the fact that the furnace itself could not be insulated because of the excessive temperatures on available refractories has detracted attention from the substantial economies which could be effected by insulating the checker chambers. Yet the object of this paper is not merely to discuss theoretical savings which might be accomplished through minimizing radiation losses, but is to call attention also to the highly satisfactory and very practical results which are now being accomplished on actual installations. This is a case where actual operating results far exceed the savings shown by calculations based on radiation losses alone, because insulation properly applied minimizes air leakage losses also. Furthermore, the many successful installations have proven that with suitably designed insulation the earlier fears as to possible ill effects on refractories were unfounded.

Among the advantageous results attained through the use of insulation on checker chambers are: (1) a direct saving in fuel consumed per ton of steel produced, (2) increased temperature of the preheated air and gas, (3) improved conditions of furnace atmosphere, due to reduced air leakage, (4) increased speed of heats, (5) increased production, (6) decreased losses during Sunday shut downs, and (7) increased temperatures in gases delivered to waste heat boilers resulting in increased steam production. All of these results have been secured in varying degrees in a great many actual installations. In some cases the saving in fuel has been the outstanding advantage. In others increased speed of heats and increased production have been most noticeable. In still others the most notable feature was increased steam production in the waste heat boilers. Naturally, with varying conditions of operation the various items will not show up in the same proportion in each installation, but in every installation investigated it was found to be unmistakably apparent that highly desirable results were being obtained, and this without detrimental effect on the brick work where insulation was properly proportioned to the conditions involved.

---

*To be presented at A. I. & S. E. E. Annual Convention, June 25-28, 1928.

†Consulting Engineer, Johns-Manville Corporation, New York.

Heat Losses From Walls and Roofs

Some conception of the magnitude of losses from walls an droofs of regenerators is obtained by noting on Fig. 1 the large heat losses at the temperatures commonly observed on these surfaces. Yet this is by

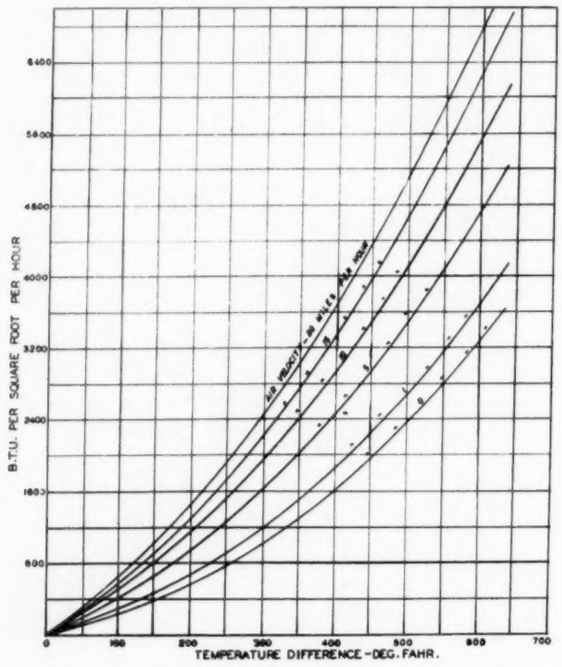


FIG. 1—Heat losses from uninsulated hot surfaces.

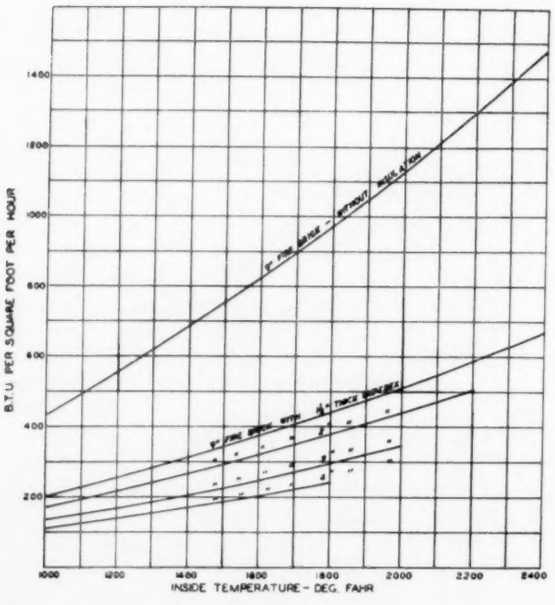


FIG. 2—Heat losses through uninsulated and insulate walls and roofs 9" fire brick (air temperature 80°.)

no means the whole story. There are cases where the spaces around the checker chambers are well ventilated and relatively cool with correspondingly lower wall surface temperatures, yet where the losses are undoubtedly greater than in others where the chambers are in confined spaces where much higher temperatures prevail. In still other cases, the rate of air infiltration through the walls is such that the temperature of the wall may be deceivingly low. In such cases it is true that losses by radiation may not be excessive, but air infiltration losses in such cases are none the less real and preventable losses.

The best means of estimating the savings in heat transmission losses is through the use of calculations based on the thicknesses and conductivities of the materials and the temperature conditions involved. Such computations show that in reduced transmission losses alone, the insulation of checker chambers is fully justified, and the saving through reduction of infiltration losses is just so much more net gain.

For convenience, results of such computations are shown in Figs. 2, 3, 4 and 5 for various thicknesses of brick walls and roofs and for various thicknesses of insulation. The conductivities of firebrick vary over a considerable range therefore, in order that the savings computed from these charts be conservative rather than exaggerated, the conductivities of firebrick used

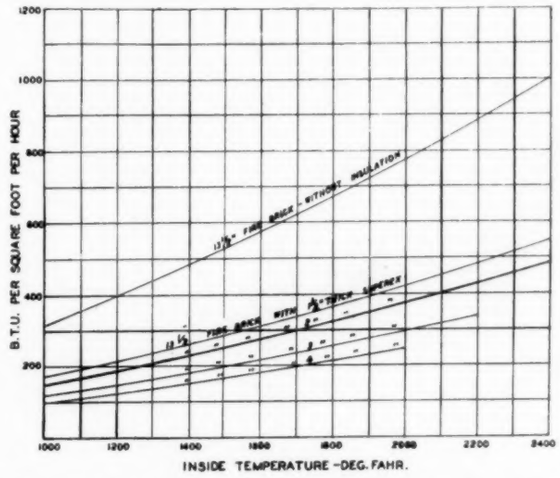


FIG. 3—Heat losses through uninsulated and insulated walls and roofs 13½" fire brick (air temperature 80°.)

in preparing the charts were purposely taken in the low rather than the high portion of the range. The values used varied from 6.0 B.t.u. per square foot, per degree temperature difference per 1 inch thick, per hour at a mean tempreature of 1000 degrees Fahrenheit, to 8.77 at 2600 degree Fahrenheit. A higher conductivity of the brickwork would result in higher losses from the uninsulated constructions than those shown in the charts. The losses through the insulated walls would be increased somewhat also, but to a much smaller degree than for the uninsulated; therefore, under such conditions the savings would be greater than shown in the charts.

Value of Savings Effected by Insulation

What these savings in B.t.u. per hour really mean is best visualized by expressing them in terms of savings in dollars per 100 square feet per year. This may readily be accomplished through the use of Fig. 6. This chart takes account of various operating periods in hours per year and of different values of the heat saved. For example, in the case of a 13½" roof at an

average inside temperature of 2400 degrees F., the saving in B.t.u. per hour by 2″ thick insulation is 443 B.t.u. (see Fig. 3). If the furnace is operated 6000 hours per year the equivalent saving in dollars per square foot is found from Fig. 6 to be 53c, or $53

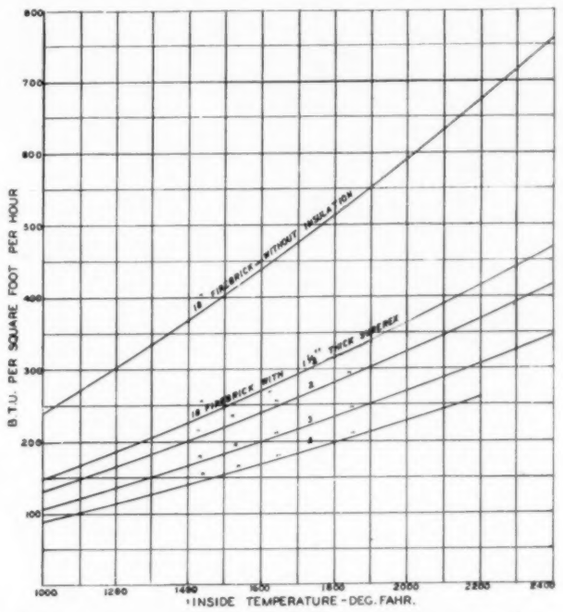


FIG. 4—Heat losses through uninsulated and insulated walls and roofs 18″ fire brick (air temperature 80°.)

per 100 square feet per year, even at a value of heat of only 20c per 1,000,000 B.t.u. This annual saving is considerably more than the cost of the insulation: so that the cost is repaid in a few months' operation, after which the saving is clear net gain. In fact, from

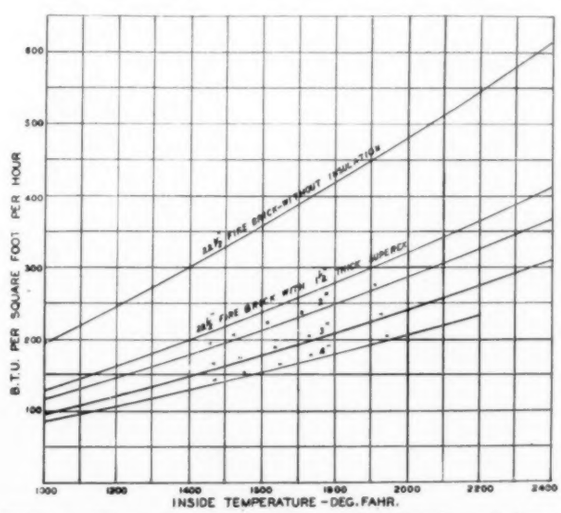


FIG. 5—Heat losses through uninsulated and insulated walls and roofs 22½″ fire brick (air temperature 80°.)

the heat saving viewpoint, the use of much thicker insulation would be justified, but other practical considerations which will be discussed later make it advisable to limit the thickness of efficient insulation on the roofs to about 2″, which successful installations have shown to be entirely safe.

On side walls, however, thicker insulation may be used and the heat loss reduced to a more economical basis, without fear of danger to refractories; because the brick work is thicker, and the average temperatures are lower. It is true that the temperatures to which the upper portions of the side walls are exposed are the same as those under the roof, but the omission of insulation at the skew back and the downward flow of heat through the thick wall to the cooler lower portions, prevent the raising of the mean temperature of the wall to a dangerous point even in the case of the portion above the checkers. Referring to Fig. 4, the saving by 4″ thick insulation on an 18″ thick fire brick wall at an average inside temperature of 2000 degrees Fahrenheit is shown to be 365 B.t.u. per square foot per hour. This is equivalent to a saving of $44 per

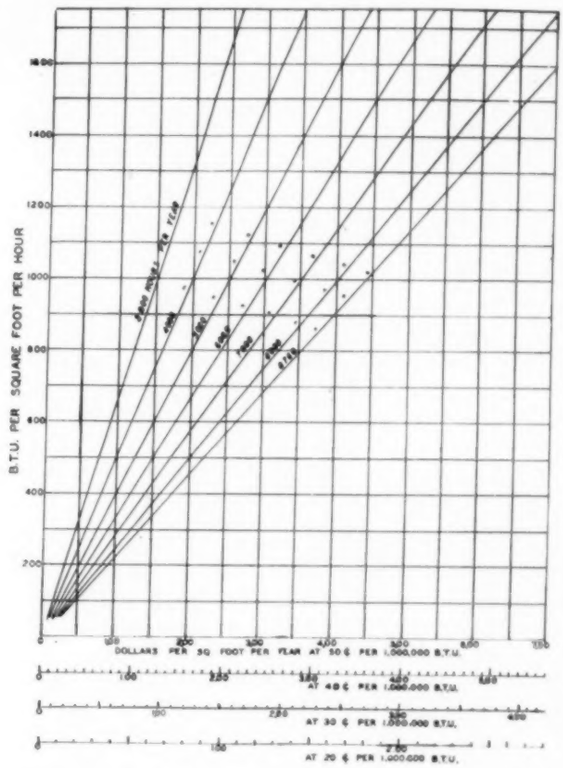

B.T.U. PER SQUARE FOOT PER HOUR
DOLLARS PER SQ FOOT PER YEAR AT 50 ¢ PER 1,000,000 B.T.U.
AT 40 ¢ PER 1,000,000 B.T.U.
AT 30 ¢ PER 1,000,000 B.T.U.
AT 20 ¢ PER 1,000,000 B.T.U.

FIG. 6—Cost of heat losses in dollars per year.

100 square feet per year on the basis of 6000 hours' operation and a value of heat of 20c per 1,000,000 B.t.u. This saving is sufficient to pay a return of about 70 per cent on the investment represented by the cost of insulation. A thickness of insulation of 3″ to 4″ is clearly justified on these portions of the side walls.

The charts may also be used to determine which of two thicknesses of insulation is the more economical. For example, under the conditions of the last example the additional saving by 4″ thick insulation as compared with 3″ thick is 40 B.t.u. per square foot per hour. This is equivalent to 4.8c per square foot per year, or $4.80 per 100 square feet per year. If the cost of the additional 1″ thickness of insulation is 16c per square foot, the additional saving pays a return of 30 per cent on the additional investment. Therefore, under the conditions of the example, the

4″ thickness would be more economical than the 3″. With a longer period of operation per year, or more costly heat, the greater economy of the 4″ thickness would be more pronounced, and if the value of heat is greatly increased much thicker insulation would be justified. The latter statement, however, applies more particularly to furnaces and equipment other than open-hearth checker chambers as on these, 3″ to 4″ thicknesses of insulation are usually sufficient to give most economical results.

In connection with the solution of the above example, it will be noted that 40 B.t.u. per hour is below the range of the curves in Fig. 6. However, since Fig. 6 is in reality simply a multiplication chart and the curves are straight lines, the divisions on the vertical scale may be considered as tens instead of hundreds, in which case the required answer will be one-tenth of the value read from the horizontal scale. In the above example, where it is desired to find the dollars per year equivalent to 40 B.t.u. per hour, the equivalent value corresponding with 400 B.t.u. per hour is found from the chart to be 48c per year. The required answer is one-tenth of 48, or 4.8c per square foot per year. This procedure greatly enhances the accuracy of the chart where the amount of heat to be converted to its equivalent in dollars per year is less than 170 B.t.u. per square foot per hour.

Savings Expressed as Percentages of Total Fuel Cost

The desirability of insulating open-hearth checker chambers was forcibly brought out in the classical paper on The Thermal Efficiency and Heat Balance of an Open-Hearth Furnace, by Kinney and McDermott*, in which it was shown that the radiation losses from gas and air checkers and uptakes amounted to 7.85% of the total heat in the fuel to the furnace. Other estimates have been far higher, but basing conclusions on the more conservative figure, of which approximately one-half may be conserved by the use of suitable insulation, the savings which are effected are very attractive. Even one per cent of the annual cost of fuel for an open-hearth furnace is quite a sizeable item, and the total saving by the insulation of checker chambers, including its effect on reducing air leakage, is many times this amount. Therefore, it is certain that the cost of such insulation is usually repaid in less than one year's operation.

Referring to the question of savings in terms of total fuel cost, a word of warning in connection with such percentages is in order. Percentages are very useful if properly interpreted. When misinterpreted, they are likely to be highly misleading. A saving of three, five, or even ten per cent might look small in comparison with total costs or with savings which might be effected in other directions, as by more careful operation, etc. **The true perspective is obtained by comparing the annual saving with the annual cost of effecting that saving,** regardless of what percentage relationship these bear to the total operating cost. In the case of insulation, the saving may appear to be small when expressed as a percentage of the total fuel bill, but likewise the annual cost of the insulation is a still smaller percentage of that small total fuel bill; therefore, the saving looms large when compared with the cost of effecting it.

*Proceedings American Iron and Steel Institute, 1922.

Another feature about insulation which is not generally understood is that the saving is practically independent of other savings which may be effected, through improved operation, etc. This is best illustrated by the analogy of transporting by motor truck a consignment of mercury or other valuable liquid in a keg with a leaky spigot and an open bunghole. Careful driving might minimize the loss through the bunghole, but could not stop the leakage at the spigot. On the other hand, if a dollar spent for tightening the spigot stops the wastage of five dollars worth of liquid, the net saving is four dollars regardless of whether a means of completely plugging the bunghole is found or not and regardless of whether the total value of the contents of the keg is ten dollars or one hundred dollars. Yet the percentage would be quite different in each case.

It might be argued that it was putting it too strongly to say that the conception of surface temperature as an accurate measure of heat loss is a fallacy. Every one who has been in close proximity to a very hot surface knows from his own experience that such a surface is dissipating large quantities of heat. That much is true. Yet it by no means follows that another surface at not quite so high a temperature is losing less heat. It may be losing far more. That is why the concept of surface temperature as a measure of heat loss should be recognized as a fallacy. It is one of those half truths which are so dangerously misleading.

It has already been pointed out that the temperature of surrounding air has a corresponding effect on the surface temperature. That is, if the air temperature is lower, the surface temperature will be lower also, if all the other conditions are the same. It might be argued then that, admitting that surface temperature alone is no measure of heat loss, temperature difference between surface and air might be such a measure. But is it? That argument is simply retreating from a wholly untenable position to one which is but little more defensible. Once it is admitted, as it must be, that there is one variable other than heat loss which affects surface temperature, it must also be admitted that there are still at least half a dozen others which have to be considered. The result is that the entire surface temperature theory becomes so complicated that it collapses of its own weight.

It is only necessary to consider the effect of two other variables in order to show the utter unreliability of surface temperature as a measure of heat loss. In Fig. 7, the lower curve shows the temperature differences from surface to air at various heat losses when the surface is exposed to an air velocity of 10 miles per hour. If the velocity were higher, the curve would be still lower. The middle curve represents what might be called normal conditions were it not for the fact that these conditions so rarely obtain around actual furnace installations. At any rate, the conditions are: Still air except for convection currents, and radiation only to surfaces at the same temperature as that of the surrounding air. The upper curve represents conditions similar to those for the middle curve, except that surfaces receiving radiation from the wall are at the same temperature as the wall itself, as, for example, in the case of closely adjacent parallel walls of similar furnaces. Strictly speaking, this curve would not apply to parallel walls of finite extent, because of

radiation that escapes at the ends and upward and downward from the space between the furnaces. Yet the curve serves to illustrate the point; because a few doors in the walls, which were at much higher temperatures than the walls themselves, would make up the deficiency, and if the doors were of considerable extent, it is readily possible that their effect would result in a curve still higher than that shown.

Therefore, at a temperature difference of 50 degrees between surface and air, you have your choice of 50, 100 or 200 B.t.u. per square foot per hour. And at higher temperatures the range of variation is still greater. Likewise, for a given heat loss of 100 B.t.u. per square foot per hour, the temperature of the surface may be 25 degrees, 50 degrees or 100 degrees above the air temperature. Again you have a range of choice of some four hundred per cent.

But that still is not the entire story. Referring to Fig. 8, curves of surface temperatures for a wall of given construction are shown for the three conditions described above in connection with Fig. 7. The actual surface temperature for a given inside temperature will probably be somewhere between the upper and

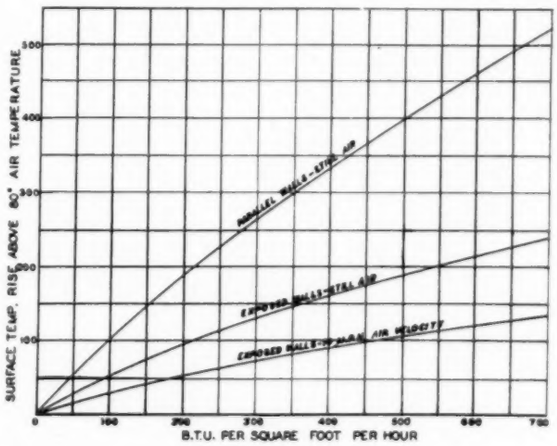


FIG. 7—Temperature differences surface to air as a function of heat loss.

lower curves (provided there is not such a high air velocity or such a rate of air infiltration that it will be below the lower curve). Again there is a range of of choice of surface temperatures which should appeal to the imagination, but in Fig. 8a, note how little these widely varying **exterior** conditions affect the total rate of heat loss through the wall. And the irony of it all is that the exterior condition which produces the **lowest surface temperature** is the one which causes the **greatest loss through the wall.**

What does all of this discussion of surface temperatures have to do with the subject matter of this paper? The answer is simply this: The belief is entirely too prevalent that the results accomplished by insulation may be judged on the basis of its effect on surface temperatures. Certainly, the insulated surface is generally much cooler, but this fact alone does not, by any means, show the true comparison on a quantitative basis. Surface temperatures are too erratic for that. Nor does the expedient of comparing surface temperatures on two furnaces side by side help very much. This is often done on the theory that then all of the variable conditions of air temperatures, air circulation, etc., will be eliminated because the conditions for the two furnaces will be exactly the same. Generally they will not be, but supposing, for the sake of argument that the conditions were the same, the surface temperature on the insulated wall will be higher than it should be, because of radiation across the alleyway from the uninsulated furnace. And, conversely, the surface temperature on the uninsulated wall will be lower than it was before the other wall was insulated, because of diminished radiation from that direction. Furthermore, if air infiltration through the uuinsulated wall is excessive, its surface temperature will be still further decreased so that a comparison of surface temperatures will mean just nothing at all.

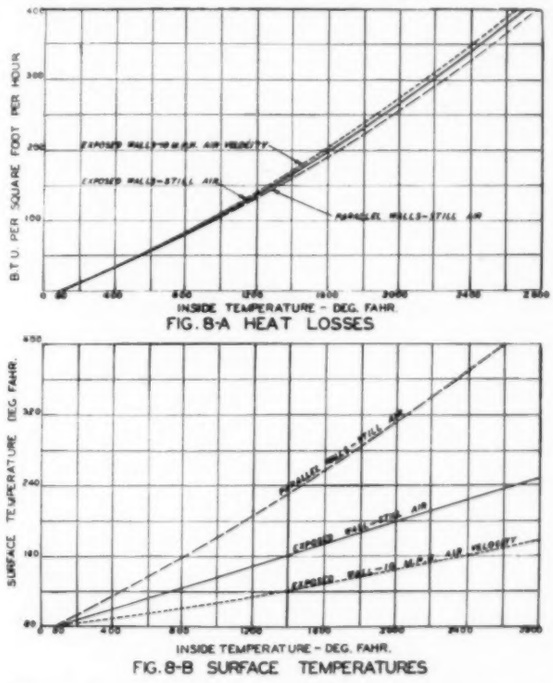

B.T.U. PER SQUARE FOOT PER HOUR
INSIDE TEMPERATURE - DEG. FAHR.
FIG. 8-A HEAT LOSSES
SURFACE TEMPERATURE DEG. FAHR.
INSIDE TEMPERATURE - DEG. FAHR.
FIG. 8-B SURFACE TEMPERATURES

FIG. 8—Heat losses and surface temperatures 18" fire brick wall with 3" insulation (air temperature 80°F.)

If some sort of check test is required, what should be done is to measure the temperature gradient in the wall. This method is unsatisfactory enough, but at that, it is at least ten times as satisfactory as surface temperature tests.

Insulation of New and Old Checker Chambers

The thicknesses of insulation for most economical results have already been discussed under the subject of Value of Savings Effected by Insulation. Fig. 9 shows a typical installation of new checker chambers, illustrating the insulation used on the various portions of the chambers. The walls above ground and to a point about one foot below grade are insulated to a total thickness of 3¾ inches with block insulation applied in two layers so that the second layer overlaps all of the joints in the first layer. Actual temperature measurements on checker chamber walls insulated in this manner have shown an average of approximately 1200 degrees Fahrenheit between the insulation and the fire brick. This increased temperature at the outer surface of the brick demonstrates the effectiveness of

the insulation in limiting heat flow through the wall and yet is not so high as to result in a dangerously high mean temperature in the brick work.

The roofs are insulated to a total thickness of 1¾ inches with 1¼ inch thick block insulation and ½ inch cement. The use of as thick insulation on the roofs as on the side walls should not be recommended, but observed temperatures averaging approximately 1100 degrees Fahrenheit between the 1¾ inch construction described above and the brick work indicate that the thickness of block insulation could be increased to 2 inches without endangering the brick work. The fact that the temperatures under the roof are not maintained continuously at the maximum point and that the peaks are of very short duration, insures that the mean temperature of the brick work is well within the range of safety. Only the surface of the brick is subjected to the maximum temperature, and only a comparatively small portion of the thickness of the brick is subject to any wide variations in temperature. No measurable variation in temperature was observed at the point between the insulation and the brick throughout the cycle of regeneration.

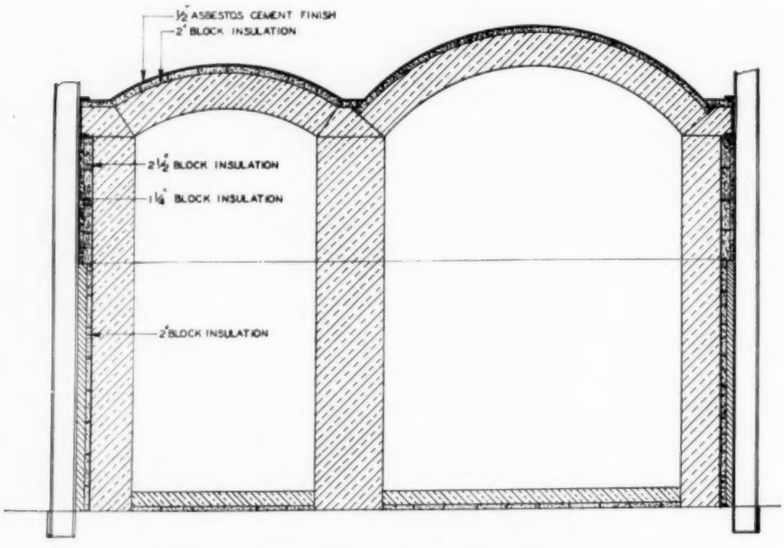


FIG. 9—Typical insulated checker chamber.

The walls below grade and the floors of the chambers are insulated with 2 inch thick block insulation. It was formerly the general belief that, because of the resistance to heat flow offered by dry earth, insulation was not required on the underground portions. However, a more thorough analysis of the situation shows that the use of some insulation on these portions is highly advisable, but probably the thickness used should not exceed 2 inches. The earth may not in most cases be dry at any very great depth below the chambers, and the evaporation of moisture which penetrates into the dry zone around the furnaces represents a very considerable expenditure of heat. Furthermore, the theory as to the relative insulating effect offered by the dry earth is based on the so-called "steady state" of temperatures. But this steady state is not even approximately attained for many months after the furnace starts up. All the while during this period heat is being dissipated to increase the temperature of the surrounding earth, and before this rate of dissipation becomes negligibly small the furnace is shut down to be reconditioned for another campaign. Still another justification for insulation on these portions is, of course, the protection which it affords to the foundations and steel buckstays.

The insulation of existing checker chambers is just as important as in the case of new ones. In some cases it may be even more important, because of the effect of insulation in minimizing air infiltration losses. The block insulation itself provides a very considerably increased resistance to air leakage and, furthermore, the outer surface of the insulation may be maintained more effectively airtight than the bare brick wall. The walls above grade and the crowns may be insulated as described above for new furnaces except that in cases where rebuilding is anticipated within a few years the thickness of insulation may be reduced somewhat, as for example, to 3 inch thickness on the walls and 1½ inch thickness of blocks on the roofs. The insulation of the underground portions of old checker chambers should, of course, be deferred until the time of rebuilding. But, since the savings by insulation of the above ground portions repay the cost very quickly, even a very few years' use would make that part of the work a profitable investment.

Conclusions

By way of summary, it may be said that the benefits derived from the insulation of open-hearth checker chambers have been thoroughly proven by actual operating results on a great many installations on both old and new chambers and over a period of years. The savings in fuel per ton of steel produced, the increased speed of heats, the diminished air leakage, the increased amounts of steam produced in waste heat boilers and the satisfactory service given by insulated checker chambers are not merely theoretical deductions, but are actual accomplished facts. Therefore, this is a field where very material savings will accrue to the industry through giving attention to the insulation of checker chambers not only on new, but also on existing furnaces. The same reasoning applies none the less forcibly to a great many other furnaces in the steel and allied industries.

Arrange to Visit Every Booth

While At The

IRON & STEEL EXPOSITION

June 25 to 28

Hotel Stevens **Chicago, Ill.**

*Recording and Controlling Instruments in the Iron and Steel Industry**

By C. C. EAGLE AND ROY M. WALKER†

IN the preparation of this paper, which deals with the use and value of recording and controlling instruments in the Iron and Steel Industry, it was considered advisable to confine our discussion to only those applications that bear upon the metallurgical phase of the industry. For instance, the power house, which is manifestly an essential part of almost every iron and steel plant, is passed over and no mention made of the many applications requiring pressure and vacuum gauges and thermometers, etc., except insofar as they are mentioned in connection with some of the plant equipment which is dependent upon steam from the power house.

It was felt that it would be intensely interesting to the average man who is in any way connected with the Iron and Steel Industry, to start with the use of recording and controlling instruments in the iron and coal mines and the limestone quarry, and trace their use through the blast furnace, the coke oven and by-products departments, etc., right down through the other departments such as the tube and rod mill, the sheet and tin plate mill, until the former ore leaves as a finished product.

From the following list of instruments, which are classified according to the departments in which they are used, it will be noted that practically every type of recording instrument manufactured serves some purpose in the Iron and Steel Industry. It might be interesting to state at this time that as a result of a study of steel plant operation and the apparent need for recording heat measuring instruments in the industry, Prof. W. H. Bristol early in the 1900's, began a series of experiments involving the use of base metal thermo-couples, which resulted in the development of an inexpensive thermo-couple and practically revolutionized the use of the pyrometer and brought its cost so low that it could be universally employed.

In going through these long lists of instruments on the various applications, it will be realized that no where near all of these are used in any one plant. Some plants will use recorders on some applications, while other plants will use them on entirely different applications. The idea here is to bring out every possible application on which a recorder is used.

Starting with the iron and coal mines and limestone quarry the applications and instruments are shown in the accompanying tabulated list.

One very interesting development in connection with coal mine ventilation is the apparent need of a recording instrument in the nature of a tachometer to show the displacement of air in the ventilating duct.

The instrument most commonly in use at the present time is a low range vacuum and pressure gauge to record the vacuum or pressure developed by the ventilating fan. It has been disclosed that even though an obstruction in the way of a cave-in would shut off the supply of air to the mine or would cut off the exhaust of the gaseous air, the fan would still be running and the recording vacuum and pressure gauge would be showing a static head.

The installation of an anemometer connected to a magneto at some suitable location in the ventilating shaft, and the magneto electrically connected to a recording tachometer, would show at all times whether or not there was a proper supply of fresh air or a withdrawal of impure air.

Passing on from the mines and quarry, we come to the coke ovens and by-product department, where the coal is reduced to coke and in this process practically all volatile substances are driven off and reclaimed in one form or another.

The instruments used in this department make up a very impressive list and are also given in the tabulated list under their proper heading.

It will be noted that practically every instrument used in the by-product department has the moisture fume and dust proof case. The nature of the work demands this type of case, as the vapors and fumes encountered in the various steps have a tendency to corrode and impair the clock and the recording system if permitted to come in contact with them.

While rubber gaskets are generally used to make the case tight, it has been found that in the benzol department, the rubber soon becomes lifeless, losing its elasticity or resiliency, and as a result a felt, or some other form of gasket, must be used.

In referring to the ranges of the charts, it will be seen that some are given in inches head of water or mercury, others in millimeters or centimeters head of water or mercury, and still others in millimeters and centimeters head of kerosene. As some operators prefer one unit and others prefer quite a different unit, it has been necessary to furnish charts in equivalent ranges, which means quite a duplication of charts for the same application.

From the coke department, the coke is traced to the blast furnace department where it joins the ore and limestone and plays such an important part in the fusion of these two elements, resulting in the formation of pig iron.

Here again, a large number of recording instruments are employed and are given in the list below.

One rather interesting feature of blast furnace operation is, that there seems to be more of an unanimity of opinion concerning the applications on which recorders are required. Of course, there are different types of instruments used for accomplishing the same results in the same process. For in-

*To be presented at A. I. & S. E. E. Annual Convention, June 25-28, 1928.

†Elec. Engrs., The Bristol Company, Waterbury, Conn.

stance, on waste heat temperatures of the stoves and top gas temperatures, some employ pyrometers and others, thermometers.

It would appear that evolution is going on more rapidly in this one department than any other department of the steel plant.

One of the most recent developments is the hot blast control for automatically operating the mixer valve thereby maintaining a more nearly uniform temperature in the hot blast line.

There is, also, the electric precipitator, which removes the dust from the top gases after they have passed through the dust catcher. The precipitator consists essentially of vertical steel tubes, plates or

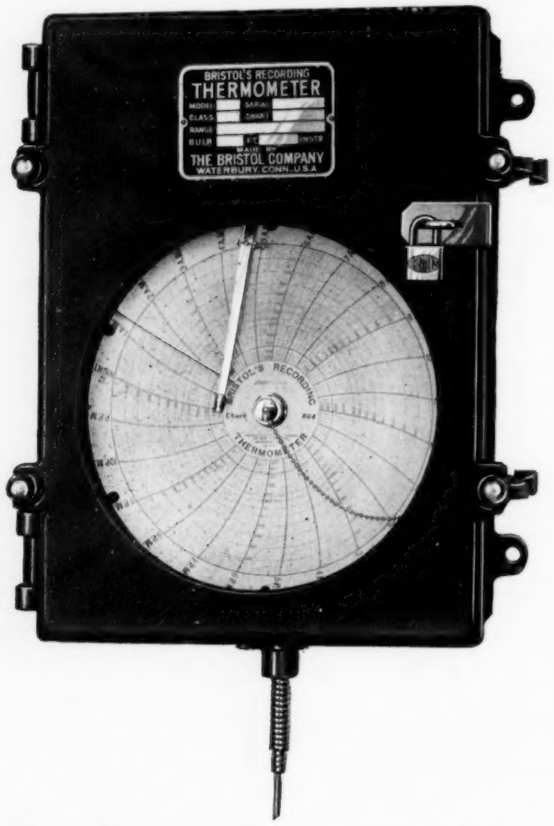


FIG. 1—Moisture proof thermometer with inverted fountain pen for coke plants and steel mills.

reinforced concrete slabs, with highly negativily charged wires inside the tubes or between the plates or slabs. The dust particles are precipitated against the inside of the tubes or against the plate or slabs and either fall to the bottom or are jarred loose. On this application, the usual recording thermometer for top gas temperature, and the recording gauge for top gas pressures are used, but there is also a demand for voltmeters and wattmeters for showing that the proper voltage is maintained and for indicating short circuits.

Still another interesting development is the use of the pressurestat for automatically lifting the thermo-couple in the hot blast main into the lining of the main 5 or 6 inches, during back drafting, to protect it from injury due to the intense heat encountered in back drafting. The drop in pressure when the hot blast is taken off causes the pressurestat to actuate the power unit geared to the thermo-couple, lifting it into the lining. When the hot blast pressure is restored, the pressurestat again energizes the power unit and the thermo-couple is forced down into the hot blast main.

FIG. 2—3 pen recorder for blast furnace stoves.

In one of the large midwest plants, the fuel gas lines to the stoves are equipped with gasometers and butterfly valves, which maintain the pressure at approximately 10 in. head of water. This insures very uniform combustion at the burners.

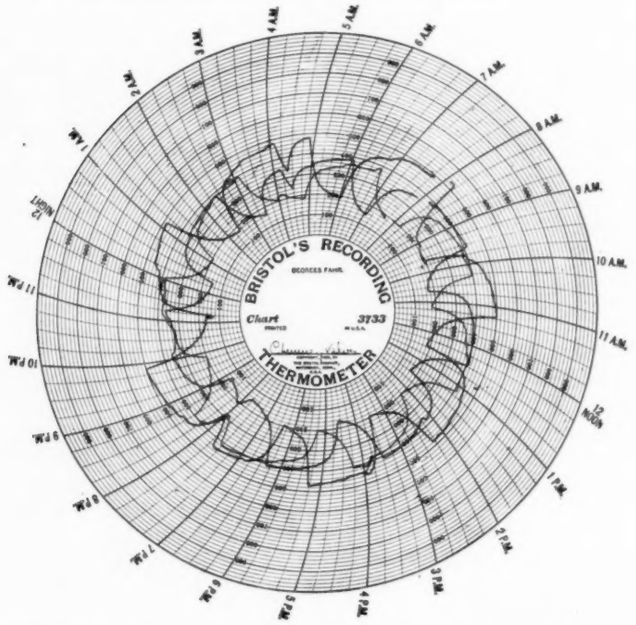


FIG. 3—Ink record in colors of temperatures at chimney valves of stoves of a blast furnace.

This same plant has standardized on reversed scale charts for all pressure gauges used on the blast furnace. This style of chart has the advantage of throwing the normal working range to the outer part of the chart where the time arcs are considerably further apart. In this way, the record is opened up considerably and it is easier to determine the time represented by pressure fluctuations. Specimens of these charts are reproduced here.

COAL AND IRON MINES AND LIMESTONE QUARRY

Application	Instrument	Range	Purpose
Ventilating system	Round chart moisture proof recorder	4 in.-0-4 in. water	Check on operation of ventilating fan.
Ventilating system	Strip chart or round chart tachometer	In ft. per min. velocity of air	Check on proper supply of fresh air to mine.
Hoist drums	Strip chart tachometer	0-100 r.p.m.	Check speed of hoist drum.
Line voltage	Round or strip chart model recorder	As required	To check voltage on system.
Power consumption	Strip chart watt-meter, switchboard or portable	As required	To check on power delivered to different departments and to test motors.
Power consumption D.C.	Round or strip chart ammeter	As required	To check operation of D.C. motors.

BY-PRODUCT COKE PLANT

- Pressure & Vacuum Gauges -

Blower for gas producer	Moisture proof model recorder	0-32 in. wtr. pressure	Check on air pressure available.
Under producer grates	Moisture proof model recorder	0-12 in. wtr. pressure	Check on proper air supply.
Top of producer	Moisture proof model recorder	6 in. wtr.vac. -0-24 in. wtr. pressure	To show that gas is being generated rapidly enough to take care of demand.
Steam pressure for water gas set	Moisture proof model recorder	0-100 lbs. pressure	To maintain max. efficiency
Ash pit of generator	Moisture proof model recorder	0-8 in. wtr. pressure	To insure proper fuel bed condition.
Oven stack draft	Moisture proof model recorder	0-30 or 50 mm. water vacuum	To control stack pull in main waste gas flues.
Pressure of fuel gas for heating ovens	Moisture proof model recorder	0-150 mm. wtr. pressure	To insure proper feed of gas to fuel system as check on measuring device.
Before and after service wtr. pumps	Moisture proof model recorder two-pen	0-80 lbs. pressure	To insure proper supply of water.
Coal gas hydraulic main	Moisture proof model recorder	0-10 mm. wtr. pressure	To limit suction of exhauster and prevent abnormal mixture of air being pulled out to flue system.
Gas before exhauster	Moisture proof model recorder	0-50 cm. ker. vacuum	To show obstruction in line.
Gas after exhauster	Moisture proof model recorder	0-50 in. wtr. pressure	For regulation purposes.
Water line to primary cooler	Moisture proof model recorder	0-100 lbs. pressure	To insure proper head on spray.
Gas leaving primary cooler	Moisture proof model recorder	0-500 mm. ker. vacuum	To show obstruction.
Steam line by-product building	Moisture proof model recorder	0-250 lbs. pressure	To check proper steam pressure.
Gas before tar extractor	Moisture proof model recorder with seal	0-400 cm. wtr. pres. or 0-55 in. wtr. pres.	To show obstruction and determine exhauster slippage.
Gas before reheater	Moisture proof model recorder with seal	0-400 cm. wtr. pressure	To show loss of pressure in tar extractor.
Gas before and after saturator	Moisture proof model recorder with coil	0-400 cm. wtr. pres. or 0-55 in. wtr. pres.	Gives idea when saturator needs cleaning and condition of holes in lead bells and lining.
Tar flushing discharge piping leaving building	Moisture proof model recorder with coil	0-100 lbs. pressure	To indicate obstruction by tar and pitch deposits.
Exhaust header to ammonia still	Moisture proof model recorder	0-32 lbs. pressure	To check on steam delivery to ammonia still.
Ammonia spray discharge	Moisture proof model recorder	0-100 or 0-25 lbs. pressure	To insure proper head.
Pressure top and bottom of ammonia still	Moisture proof model recorder two-pen	0-80 cm. merc. pressure	To check seals.
Pressure of steam for heating benzol still	Moisture proof model recorder	0-200 lbs. pressure	To insure proper supply.
Pressure of benzol vapor at bottom of oil still	Moisture proof model recorder	0-5 lbs. pressure	To check functioning of still.
Pressure after light oil absorber	Moisture proof model recorder	0-200 cm. ker. pressure	Check on operation.
Pressure top and bottom of light oil still	Moisture proof model recorder	0-80 cm. ker. pressure	Check on operation.
Gas before final cooler	Moisture proof model recorder	0-400 cm. wtr. pressure	To show obstruction.
Gas after final cooler	Moisture proof model recorder	0-200 cm. ker. pressure	To show obstruction.
Gas line before booster	Moisture proof model recorder	0-10 lbs. pressure	Check booster operation.
Pressure after booster	Moisture proof model recorder	As required	Gas pressure must meet city specifications.
Wash oil stills	Moisture proof model recorder	0-25 lbs. pressure	To insure continuous feed.

BY-PRODUCT COKE PLANT

Application	Instrument	Range	Purpose
	- Thermometers -		
Air and steam temperature under hearth of gas producer	Moisture proof model recorder	30-175° F.	To get max. B.t.u. from coal and prevent clinkering.
Control of blast temperature under grate	Temp.indicator elec.contacts	30-175° F.	Control temperature of blast under grate.
Fuel gas at battery	Moisture proof model recorder	-0-150° C.	To prevent blocking by napthalene and to guide in regulating temperature of ovens.
Cooling liquor in hydraulic main	Moisture proof model recorder	0-400° F. 0-130° C.	To control flow of liquor and keep lines cool.
Offtake in collecting main	Moisture proof model recorder	0-150° C.	To insure proper spraying of gas.
Gas inlet to primary cooler	Moisture proof model recorder	0-150° C.	To check efficiency of equalizer and show obstruction.
Gas outlet from primary cooler	Moisture proof model recorder	0-80° C.	To control flow of cooling water and insure removal of tar.
Gas inlet far extractor	Moisture proof model recorder	0-80° C.	Guide to most efficient extraction.
Gas outlet from reheater	Moisture proof model recorder	0-100° C.	Prevent accumulation of water in saturator and accelerate reaction.
Gas inlet to saturator	Moisture proof model recorder	0-100° C.	To prevent formation of cyanides and colored salt by too low temperature.
Gas outlet at header after acid separator	Moisture proof model recorder	0-70° C.	To check functioning of saturator.
Tar flushing line leaving building	Moisture proof model recorder	0-150° C.	Check temperature of liquor required for cooling gases.
Lime and liquor entering fixed still	Moisture proof model recorder	0-150° C.	To insure heated lime solution to regulate inlet steam.
Ammonia liquor leaving preheater	Moisture proof model recorder	0-110° C.	To insure proper reactions in still.
Ammonia vapor leaving still	Moisture proof model recorder	0-130° C.	To insure proper reactions in still.
Ammonia vapor entering dephlegmator	Moisture proof model recorder	0-110° C.	To insure proper functioning of dephlegmator.
Ammonia vapor header after dephlegmator	Moisture proof model recorder	50-150° C.	To insure proper functioning of dephlegmator
Ammonia vapor entering condenser	Moisture proof model recorder	0-110° C.	To insure proper functioning of condenser.
Water to final cooler	Moisture proof model recorder	0-50° C.	To regulate amount sprayed.
Gas entering benzol scrubber	Moisture proof model recorder	0-80° C.	To show proper scrubbing.
Gas after benzol scrubber	Moisture proof model recorder	0-75° C.	To determine absorbtion of benzol vapor by light oil
Gas entering and leaving final cooler	Moisture proof model recorder two-pen	0-100° C.	To show obstruction and insure proper cooling.
Water inlet and outlet final cooler	Moisture proof model recorder	50-175° C.	To regulate cooling and indicate amount of water used
Wash oil entering wash still	Moisture proof model recorder	50-175° C.	To insure proper processing and show operation of heat exchanger.
Wash oil entering and leaving final heater	Moisture proof model recorder two-pen	50-175° C.	To insure proper processing.
Temperature of vapor at ouclet of light oil still	Moisture proof model recorder	0-150° C.	Gives information concerning dry point of crude oil.
Vapors leaving light oil cooler	Moisture proof model recorder	0-70° C.	To insure proper processing.
Wash oil leaving vapor to oil heat exchanger and vapor leaving vapor to oil heat exchanger	Moisture proof model recorder two-pen	0-200° C.	To indicate efficiency of heat transfer.
Wash oil entering vapor to oil heat exchanger	Moisture proof model recorder	0-50° C.	To indicate efficiency of heat transfer.
Oil leaving wash oil coolers	Moisture proof model recorder	0-50° C.	To insure proper processing.
Oil to refining plant	Moisture proof model recorder	0-56° C.	To adjust processing.
Water to motor fuel apparatus	Moisture proof model recorder	0-50° C.	To insure proper processing when used in cooling.
Debenzolized wash oil entering and leaving heat exchanger	Moisture proof model recorder	50-175° C.	To indicate efficiency of heat transfer.
Temperature oil from light oil still	Moisture proof model recorder	0-100° C.	Check on dry point.
Oil inlet and outlet to wash oil cooler	Moisture proof model recorder. two-pen	0-150° C.	To insure proper cooling.
Temperature of light oil between superheater and benzol still	Moisture proof model recorder	50-200° C.	Check on temperature of vapor entering still.
Temperature of gas after pumping station	Moisture proof model recorder	0-110° C.	Shows temperature rise due to compression and extent of cooling necessary.

Plate 1

BY-PRODUCT COKE PLANT

Application	Instrument	Range	Purpose
	- Thermometers - (Cont'd)		
Humidity of gas	Moisture proof model recorder	0-100° C.	To determine heating value.
Temperature before and after spray pond	Moisture proof model recorder two-pen	0-60° C.	To check on proper cooling of condenser water.
	- Pyrometers and Miscellaneous -		
Gas producer	Indicator motor operated contact switch	75-1800° F.	To indicate temperature of gas producer outlet for regulating quality.
Ovens	Strip or round chart pyrometer	0-2500° F. or 75-1500° F.	For regulating fuel gas flow.
Reversals of combustion	Multiple pen operation recorder	Pens as required	To insure against excessive heat in oven battery.
Waste heat	Round chart pyrometer or thermometer	25-550° C.	To show efficiency of heating.
Coal bin hoppers	Operation recorder, six-pen	Chart 913	To check on filling of ovens
Pusher	Ammeter or shunt ammeter round chart	0-600 amp.	To determine when coking is complete and check on operator.
Gas holder	Mechanical motion recorder	Chart 965	Position and contents of holder.
Temperature ash pit under grate	Indicator	0-110° F.	To warn when clinker arches on grate.
Carburetor water gas set	Round or strip chart recorder	0-1600° F.	To insure proper temperature for carbonizing the oil.

BLAST FURNACE

Application	Instrument	Range	Purpose
	- Pressure and Vacuum Gauges -		
Blast pressure and volume recorder	Moisture proof model recorder	0-30 lbs. pres. and volume in cu. ft.	To check pressure and volume of air delivered to furnace.
Hot blast pressure	Moisture proof model recorder	0-32 lbs. pressure	To prevent channeling due to high pressure or formation of solid mass in center due to low pressure.
Pressure top gas	Moisture proof model recorder	0-75 in. water	To show regularity of descent of burden.
Stock levels	Moisture proof model recorder or long distance transmitter or recorder	6-0-24 ft. pressure	To determine depth of stock and movement of burden.
Pressure in bosh of manifold	Moisture proof model recorder	0-150 lbs. or 0-100 lbs. pressure	To indicate suitable pressure to assure proper circulation of water through bosh plates.
Pressure on entire water system	Long distance transmitter in multiple and receiver	0-150 lbs.	In case of pressure failure a quick check on every part of system is possible to locate failure.
Pressure of gas in primary and secondary dust catcher	Moisture proof model recorder two-pen	0-75 in. wtr. pressure	To indicate obstruction.
Gas entering and leaving cleaner	Moisture proof model recorder two-pen	0-40 in. wtr. pressure	To show obstruction.
Air pressure - cold air line	Moisture proof model recorder	0-25 lbs. pressure	To check on blower engine operation.
Pressure in clean gas main at stoves	Moisture proof model recorder	0-50 in. wtr. pressure	To check supply of gas for stoves.
Gas washer water	Moisture proof model recorder	0-150 lbs. pressure	To assure proper water supply.
Vacuum on turbo-blower condenser	Moisture proof model recorder	0-30 in. merc. vacuum	To check efficiency of turbine
	- Thermometers -		
Humidity of cold air	Wet and dry bulb thermometer recorder	-20-0-+110°F.	To determine moisture content of cold air for purpose of determining causes of changes in furnace operating conditions and correcting by possibly changing coke supply.
Temperature inlet and outlet water and inlet steam on blowing engine condenser	Moisture proof model recorder three-pen	30-220° F.	To determine efficiency of condenser.
Water entering and leaving bosh	Moisture proof model recorder two-pen	40-225° F.	For economy in regulating water supply.
Water inlet and outlet gas washers	Moisture proof model recorder two-pen	40-225° F.	To determine amount water used per 1000 cu. ft. gas and to show obstruction.
Gas temperature entering and leaving washers	Moisture proof model recorder two-pen	40-250° F.	To check up on thoroughness of washing and guard against too low temperatures; also to show obstruction.
Temperature of gas leaving heat exchanger	Moisture proof model recorder	40-400° F.	To evaporate entrained moisture and add physical heat to fuel gas.

BLAST FURNACE

Plate 2

Application	Instrument	Range	Purpose
	- Thermometers - (Cont'd)		
Incoming water to washer and outgoing gas	Moisture proof model recorder two-pen	0-150° F.	To be sure water is coming in contact with gas.
Temperature superheated steam to turbo blower	Moisture proof model recorder	200-800° F.	For maximum efficiency of turbo blower.
Chimney valve or waste heat temperature	Moisture proof model recorder one to four pens	200-1000° F.	To determine stove changes and operation.
* Bartlett Hayward Washer employs a 3-pen thermometer recording inlet, second stage and outlet temperatures.			
	- Pyrometers -		
Temperature of hot blast	Indicating and recording round chart or strip chart single or multiple	0-1600° F.	To keep uniform temperature in zone of fusion.
Automatic hot blast control	Pyrometer with electric contacts	0-2000° F.	To regulate automatically hot blast temperature.
Temperature of top gas	Indicating and recording pyrometer with round or strip chart single or multiple	0-1100° F.	To guide in charging.
Temperature of hot blast and temperature of top gas	Strip chart pyrometer duplex or multiple	0-1100° F. 0-1600° F.	Same as above.
Chimney valve or waste heat temperature	Pyrometer or thermometer, round or multiple	0-1100° F.	To determine stove changes and operation.
For furnace lining	Pyrometer indicator with switch or strip multiple	0-2000° F.	To check up on heat distribution in furnace and wearing down of lining.
For temperature of foundation under hearth	Pyrometer indicator or recorder	0-2000° F.	To check depth of salamander.
For general purposes	Direct reading portable or special test pyrometer	0-2500° F.	For checking all pyrometers.
Slag temperatures	Indicating pyrometer wall or portable	0-3000° F.	To indicate that slag is a right temperature to carry off elements not desired in iron.
	- Miscellaneous -		
Blowing engine speed	Strip chart tachometer	0-100 r.p.m.	To maintain uniform volume of air.
Skip, bells and distributor operation	Multiple pen electric time recorder	Chart 913	To check operation.
Stock level gauge, manually operated	Moisture proof gauge and liquid container	0-20 ft.	To check depth of stock and movement of burden.
Stock level gauge, automatically operated	Special Freyn design and special McKee design	0-20 ft.	To check depth of stock movement of burden.

STEEL MILL

Application	Instrument	Range	Purpose
	- Gas Producer -		
Chowning regulator	Moisture proof model recorder	0-4 in. hd. water 0-150 lbs. pressure	To check regulation of gas pressure.
Gas pressure	Moisture proof model recorder	0-8 in. hd. water	To show that gas is being generated rapidly enough to supply demand.
Steam pressure	Moisture proof model recorder	0-150 lbs. or 0-50 lbs.	To show steam pressure available or to check operation of steam pressure regulator.
Gas temperature	Round or strip chart pyrometer	0-1500° F.	To guide in maintaining high quality of gas.
Blast temperature	Moisture proof model recorder	0-175° F.	To guide in maintaining correct saturation temperature.
	- Sintering Plant -		
Speed of sintering grates (in continuous process)	Round or strip chart tachometer	0-75 r.p.m.	To check time during which dust is exposed to sintering flames.
Suction under sinter during burning period	Moisture proof model recorder	0-30 in. wtr. vacuum	Guides in maintaining proper draft; also time of loading when vacuum pans are part of the equipment.
Temperature in suction line (vacuum pan process)	Moisture proof model recorder	0-800° F.	Show interval of time required in loading and burning
Pressure of fuel gas	Moisture proof model recorder	As required	A check on the fuel supply available.
Power or electric current of the plant	Round or strip chart wattmeter or ammeter	As required	To reveal mechanical or electrical trouble and check efficiency.
Plant voltage	Round chart model	0-250 volts or as required	To indicate voltage regulation.

Plate 2

STEEL MILL

Application	Instrument	Range	Purpose
	- Rolling Mills -		
Motor loads	Strip chart wattmeter or ammeter	As required	To check efficiency and to guide in holding speed constant.
Speed of machinery	Round or strip chart tachometer	0-100 r.p.m. or 150-0-150 r.p.m. or as required	To guide in maintaining correct speed.
Temperature of hot rolls	Portable pyrometer	0-800° F.	To increase life of rolls.
	- Structural Steel Plants -		
Arc welding current	Round or strip chart ammeter	50-0-50 amps. or as required	To record time of weld and character of the work.
Air pressure	Moisture proof model recorder	0-300 lbs.	To show that satisfactory working pressures are maintained.
	- Open Hearth -		
Reversing valves at checker work	Round or strip chart electric time recorder	10, 15 or 20 min. time intervals	To show regularity in reversing valves.
Reversing valves at checker work	Pyrometer controller with motor	0-2500° F.	To automatically reverse valves when checkers have absorbed sufficient heat.
Temperatures in checkers	Portable pyrometer	0-2500° F.	To locate stoppages in checker passages.
Waste heat boilers	Duplex pyrometer strip chart	0-1600° F. or higher	To indicate efficiency of heat exchange.
Oil or tar lines	Moisture proof thermometer	30-175° F.	To guide in maintaining proper viscosity for uniform flow.
Preheater	Thermometer control with scale	30-175° F.	To condition oil or tar for flowing to burners.
Oil or tar lines	Moisture proof gauge recorder	0-25 lbs. or as required	To guide in maintenance of proper pressure for flow required.
Steam line to burners	Moisture proof gauge recorder	0-50 lbs. or as required	To show sufficient steam pressure for injecting air and oil or tar at burners.
Gas lines	Moisture proof gauge recorder	0-50 ozs. or as required	To check on pressure available.
Motor operated reversing valves at checker work	Round chart ammeter	0-50 amps. or as required	To show when valves need cleaning.
	- Soaking Pit -		
Reversing valves at checker work	Round or strip chart electric time recorder	10, 15 or 20 min. time divisions	To show regularity in reversing valves.
Reversing valves at checker work	Pyrometer controller	0-2500° F.	To automatically reverse valves when checker work has absorbed sufficient heat.
Temperatures in checkers	Portable pyrometer	0-2500° F.	To locate stoppages in checker work.
Gas line	Moisture proof pressure gauge recorder	0-50 ozs. or as required	To check pressure available.
Oil or tar lines	Moisture proof thermometer recorder	30-175° F.	To guide in maintaining proper viscosity of fuel.
Preheater	Thermometer controller with scale	30-175° F.	To condition oil or tar for flowing to burners.
Oil or tar lines	Moisture proof pressure gauge recorder	0-25 lbs. or as required	Checking pressure required to maintain flow.
Steam line to burners	Moisture proof gauge recorder	0-50 lbs. or as required	To show sufficient steam pressure for injecting air and oil or tar at burners.
Motor operated reversing valves at checker work	Round chart ammeter	0-50 amps. or as required	To show when valves need cleaning.
	- Wire Mill -		
Temperature of acid bath	Moisture proof thermometer recorder	30-220° F.	To guide in preventing pitting of material and wasting of acid.
Temperature of acid bath	Combination recorder and control with motor steam valve	30-220° F.	To automatically record and control temperature of acid bath.
Temperature in wire baking oven	Moisture proof thermometer recorder	40-600° F.	To dry lime wash.
Annealing oven temperatures	Round or strip chart pyrometer	0-1600°F.	To soften or refine material.
Annealing oven temperatures	Pyrometer controller and electric valves.	0-1600° F.	To automatically soften or refine material.
Annealing pot temperatures	Round or strip chart pyrometer	0-1600° F.	To soften or refine material.
Annealing pot temperatures	Pyrometer controller with valves	0-1600° F.	To automatically soften or refine material.
Lead annealing temperatures	Round or strip chart pyrometer	0-1600° F.	To soften or refine material.
Lead annealing temperatures	Pyrometer controller and valves	0-1600° F.	To automatically soften or refine grain structure

STEEL MILL — Plate 3

Application	Instrument	Range	Purpose
	Wire Mill - (Cont'd)		
Patenting furnace	Strip chart multiple pyrometer	0-1800° F.	To show temperatures in different furnace zones and lead bath.
Patenting furnace	Pyrometer controller and motor valves	0-1800° F.	To control temperatures in furnace or lead baths.
Galvanizing bath	Pyrometer controller and motor valves	0-1100° F.	To maintain best working temperature.
Galvanizing bath	Round or strip chart pyrometer	0-1100° F.	To check controller or to guide in holding correct temperatures.
Speed of wire Machines	Strip or round chart with magneto	0-100 r.p.m. or as required	To guide in maintaining capacity operation without harm to material or dies.
	- Electrical Department -		
Electrical power used by plant	Strip chart wattmeter	As required	To check efficiency of plant.
Testing motors	Portable strip chart wattmeter	As required	To check efficiency of motors.
Current through distributing lines	Round or strip chart ammeter	As required	To show distribution of load.
Armature baking ovens	Moisture proof thermometer recorder	40-600° F.	To guide in baking repaired armatures.
	- Laboratory -		
Laboratory furnace	Strip chart pyrometer	0-2000° F	To record heat treatment of samples.
Laboratory furnace	Pyrometer controller	0-2000° F.	To control heat applied to samples.
	- Malleable Iron -		
Coal dryer	Moisture proof thermometer recorder	40-800° F.	To guide in drying operations.
Air furnace roof temperature	Strip chart pyrometer with optical thermocouple	100-3000° F.	To aid in upkeep of refractories.
Forced draft in air furnace	Moisture proof recording pressure gauge	0-4 in. hd. water	To guide in maintaining sufficient draft when burning powdered coal.
Forced draft to cupola	Moisture proof recording pressure gauge	0-20 ozs.	To guide in maintaining sufficient draft.
Regenerative type furnace reversing valve	Strip or round chart time recorder	10, 15 or 20 min. time intervals	To show regularity in reversing valves.
Regenerative type furnace reversing valve	Pyrometer controller	0-2500° F.	To reverse valves when checkers have absorbed sufficient heat.
Temperatures in checkers	Portable pyrometer	0-2500° F.	To locate stoppages.
Waste heat boilers	Strip chart duplex pyrometer	0-2000° F.	To show efficiency of heat transfer.
Oil lines	Moisture proof thermometer recorder	30-175° F.	To guide in maintaining proper viscosity for easy flow.
Oil preheater	Indicating controller with scale	30-175° F.	To condition oil for flowing through pipes and valves.
Oil lines	Moisture proof pressure gauge recorder	0-25 lbs.	To guide in keeping oil thin enough for easy flow.
Steam line to burners	Moisture proof pressure gauge recorder	0-50 lbs. or as required	To check pressure desired for injecting oil and air.
Gas lines	Moisture proof pressure gauge recorder	0-50 ozs. or as required	To check on fuel pressure.
Motor operated reversing valve for regenerative furnace	Strip chart ammeter	0-50 amps. or as required	To show when valve needs cleaning.
Electric melting furnace	Strip chart wattmeter	As required	To check efficiency.
Electric melting furnace	Wattmeter controller	As required	To control power input.
Annealing in boxes	Pyrometer strip chart duplex or multiple	0-2000° F.	To check temperatures through proper time cycle.
Continuous tunnel type annealing furnace	Strip chart pyrometer	0-2000° F.	To record temperatures in different zones.
Continuous tunnel type annealing furnace	Pyrometer controller and motor valves	0-2000° F.	To control temperature in the different zones.
Continuous tunnel type annealing furnace	Moisture proof pressure gauge recorder with electric alarm	0-3000 lbs.	To warn of obstruction of load going through furnace.
	- Foundry -		
Core oven temperature	Moisture proof thermometer recorder with alarm	40-800° F.	To guard against burning cores.

Plate 3

STEEL MILL

Application	Instrument	Range	Purpose
	- Foundry - (Cont'd)		
Core oven temperature	Round or strip chart pyrometer	0-1100° F.	To guard against burning cores
Core oven temperature	Thermometer controller with electric valves	0-800° F.	To control core oven temperatures.
Core oven temperature	Pyrometer controller with electric valves	0-1100° F.	To control core oven temperatures.
Gas or oil fuel line	Moisture proof pressure gauge recorder	As required	To check fuel supply.
Steam line or air line	Moisture proof pressure gauge recorder	As required	To check steam or air pressure to burners.
Oil line	Moisture proof thermometer recorder	40-175° F.	To assure proper flow of oil.
Oil preheater	Thermometer controller with scale	40-175° F.	To condition oil for flowing through pipes to burners.
Centrifugal iron pipe casting machines	Round or strip chart tachometer with magneto	0-1500 r.p.m.	To guide in securing uniform thickness.
Testing cast iron pipe	Moisture proof pressure gauge recorder	0-800 lbs.	To check strength of pipe.
	- Armor Plate Department -		
Hydraulic shears	Moisture proof pressure gauge recorder	0-1600 lbs.	To check hydraulic pressure.
Presses	Operation recorder with six pens	Time divisions	To check time of operation of six presses.
	Sheet Mill -		
Normalizing furnace	Multiple recording pyrometer	0-2000° F.	To record temperature in several zones.
Normalizing furnace	Pyrometer controller with motor valves	0-2000° F.	To control temperature in various zones.
Normalizing furnace	Pyrometer recorder with optical thermocouple fixture	0-2000° F.	To record temperature of sheets.
Box annealing furnace	Strip chart duplex pyrometer	0-1800° F.	To record temperature of furnace and temperature inside the box.
Box annealing furnace	Pyrometer controller with motor valves	0-1600° F.	To preheat gas introduced in furnace or box to maintain reducing atmosphere.
Oil lines	Moisture proof thermometer recorder	30-175° F.	To check condition of oil desired for flowing to burners.
Oil preheater	Thermometer controller with indicating scale	30-175° F.	To condition oil for flowing to burners.
Oil lines	Moisture proof pressure gauge recorder	0-25 lbs.	To check pressure maintained by pumps.
Steam lines	Moisture proof pressure gauge recorder	0-50 lbs.	To check steam pressure to inject oil and air through burners.
Reheating furnaces	Round or strip chart pyrometer	0-2000° F.	To check temperature in furnace.

STEEL MILL — Plate 4

Application	Instrument	Range	Purpose
	- Sheet Mill - (Cont'd)		
Reheating furnaces	Pyrometer controller with valves	0-2000° F.	To control temperature in furnace.
Hot rolls	Portable pyrometer with special thermocouple	0-800° F.	To check roll temperatures.
Pickling bath	Combination recorder and controller with electric steam valve	30-220° F	To record and control pickling bath temperatures.
Pickling bath	Moisture proof thermometer recorder	30-220° F.	To guide in saving acid and speeding production.
Sheet and tin plate warehouse	Psychrometer recorder	30-110° F.	To guide in prevention of rust.
Galvanizing bath	Round or strip chart pyrometer	0-1100° F	To check working temperatures.
Galvanizing bath	Pyrometer controller with valves	0-1100° F.	To maintain the required temperature.
Tin bath	Thermometer or pyrometer controller with valves	0-800° F.	To maintain required temperature.
Tin bath and palm oil	Moisture proof thermometer recorder, two-pen	0-800° F.	To check temperature of the tin and oil.
Palm oil	Thermometer controller with valves	0-800° F.	To control drip of water in cooling coils and hold temperature constant.
	- Steel Tubing -		
Annealing furnaces	Strip chart pyrometer	0-2000° F.	To check temperatures in different parts of furnace.
Annealing furnaces	Pyrometer controller and valves	0-2000° F.	To control temperature in different parts of furnace.
Oil or tar lines	Moisture proof pressure gauge recorder	0-25 lbs. or as required	To record pressure from pumps or storage tanks.
Oil or tar lines	Moisture proof thermometer recorder	40-175° F	To record temperatures required to secure good flow of fuel to burners.
Preheater	Thermometer controller and valves	40-175° F	To maintain fuel in good condition to flow to burners.
Gas line	Moisture proof pressure gauge recorder	0-50 ozs. or as required	To check gas pressure available.
Pipe pickling	Combination thermometer recorder and controller exhaust steam and live steam electrically operated motor valves	30-220° F.	To check and maintain proper temperature for saving acid and speeding up production.
Pipe galvanizing	Round or strip chart pyrometer	0-1100° F.	To check working temperature and time of dip.
Pipe galvanizing	Pyrometer controller and valves	0-1100° F.	To control working temperature.
Bituminous coatings	Thermometer controller or combination recorder and control with valves	30-400° F.	To record or control correct dipping temperatures.
Steel pipe testing	Strip chart gauge with motor clock	0-3000 lbs.	To check strength of pipe.

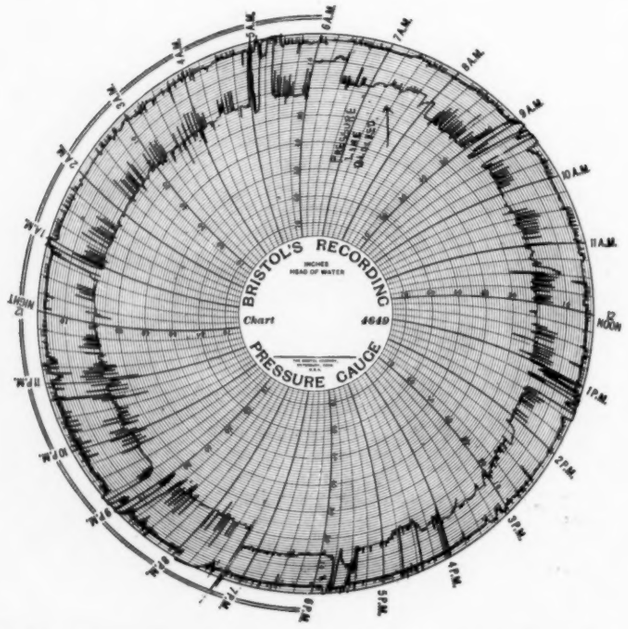


FIG. 4—Characteristic 2 pen record—gas entering and leaving washers, dryers, etc.

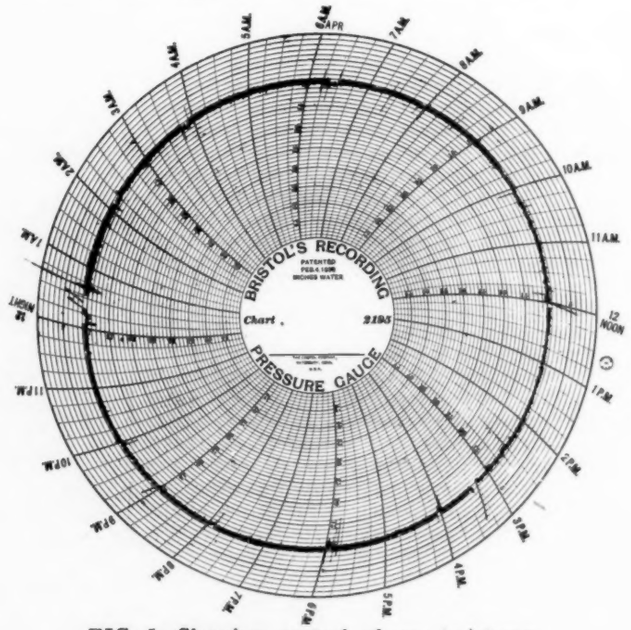


FIG. 5—Showing control of gas to stoves.

THE STEEL MILL

Instruments around the blast furnace, and even in the by-product coke plant, have become somewhat standardized due to the similarity of the various plants in which they are located. This condition does not exist to such an extent in the steel mill because of the diversity of the products handled. An attempt will be made to mention the miscellaneous instrument applications where recorders and controllers are employed in the steel mill and to state briefly the purpose for which they are installed.

Producer Gas Machines

The manipulation of a producer gas machine determines largely the relative amounts of carbon monoxide, carbon dioxide and hydrogen in the producer gas. It is, therefore, important to provide the operators with instruments to show them the conditions existing in the gas producer and to provide a record of these conditions for determining the most desirable method to follow.

An instrument frequently found in producer gas plants is a recording pressure gauge showing, on the same chart, the steam pressure used for injecting air under the fire zone of the producer and the gas pressure of the gas from the producer. This combination gauge works with a Chowning Regulator, controlling the steam flow to maintain a constant gas pressure. Without the regulator, separate recorders are more often provided for the gas pressure and for the steam pressure. For recording gas pressure, in the average steel mill, a range on the recorder of 0 to 4 in. head of water is ample; and for the steam pressure, a range as high as 0 to 150 pounds may be selected, although 30 pounds is nearer the working range. It would be better practice to install a steam pressure regulator and select a range like 0 to 30 pounds.

The gas pressure may be as low as a fraction of an inch and is recorded to show that enough gas is being generated to amply supply the withdrawals from the gas main.

The steam pressure record either checks the operation of the regulator or shows that the steam supply available is sufficient.

The recording pyrometer in the outgoing gas line is also important and in general presents a clue to the quality of the gas. Too high a temperature lowers the B.t.u. content and too low a temperature may choke the mains with carbon and tar. This gas temperature seems to be held anywhere from below 1100°F. up to almost 1400°F., subject to local conditions.

Another valuable instrument, on installations where a gas pressure regulator is not in service, is a recording thermometer, with its bulb in the blast line, to secure the correct saturation temperature in the blast. This instrument is helpful either where hand operated jet blowers or turbines blowers are used. A temperature controller may also be inserted in the blast, automatically regulating the steam introduced and holding the blast at some point like 127°F. or a little higher, depending somewhat on the grade of coal and type of producer. With turbine blowers, this controller may be desired to add live steam, as required, in the blast line, in addition to the exhaust steam from the blower. Correct blast temperature under the grates keeps down clinker in the fuel bed and greatly aids in securing a rich gas.

Sintering Plant

The judicious use of instruments greatly facilitates efficient operation in the sintering plant. Dust proof instruments are made which will stand up under the conditions found right around the sintering machinery. As the doors of recording instruments must be opened for changing charts and inking pens, it is desirable to locate the instruments outside of the sintering building when it is practical to do so. Tachometers, wattmeters, ammeters, pressure and vacuum gauges may be mounted a couple of hundred feet away from the machine without difficulty.

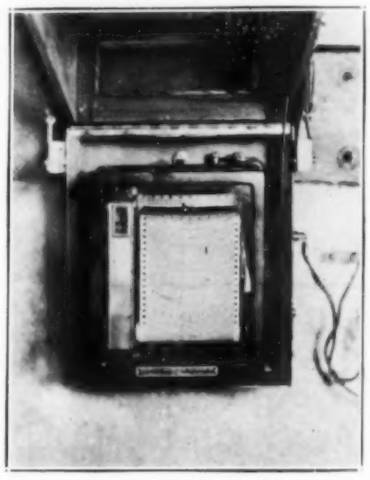


FIG. 6—Blowing engine tachometer.

A record showing the speed of the grates, in the continuous process, is very desirable. It matches up with the other records to reveal why the sinter is good or bad. Speed is varied to conform to the condition of the ore dust. A magneto built on a speeding up stand and connected through a universal joint to the grate drives, provides the electric energy to operate a recording tachometer, located most any distance away from the sintering floor.

In the continuous process, a recording vacuum gauge is regularly used to show the suction under the sinter. If the layer of sinter dust is too thick or too thin, this is shown at once by the record on the chart. Working ranges around 18 in. of water vacuum are usually reported and the chart chosen has a range from 0 to 30 in. water vacuum. Where the vacuum pan system is used, this gauge shows also the complete cycle of loading the pan, and sintering each load. A characteristic curve is inscribed which cannot be duplicated with an empty pan.

A recording thermometer gives similar information if the bulb is located in the suction line from the pan. The outgoing gases give a temperature around 400°F. and the chart has a range of 30 to 800°F.

The pressure of the gas used in sintering must be high enough to assure the heat required for sintering and is often recorded on a pressure gauge, especially when blast furnace gas or coke gas is burned and the pressure is variable.

The power required by the motors running the sintering machinery is registered on a recording wattmeter, or, on d-c. installations, it may be satisfactory to use a recording ammeter. Such instruments check the uniformity of operating conditions during each shift and show irregularities that may often be corrected. Excessive power is

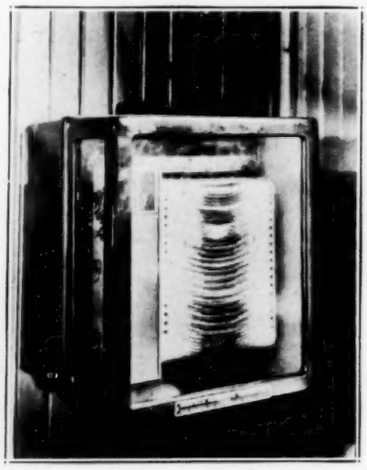


FIG. 7—Strip chart tachometer with widely fluctuating record on reversing engine.

recorded at once on the charts and brings attention to mechanical or electrical trouble, which should be investigated.

The recording voltmeter, in addition, points out the cause of difficulties when the voltage drops on the supply lines.

Rolling Mills

An important factor in a rolling mill is the speed at which the rolls are revolved. Wattmeters and ammeters are good guides where motors are installed. For steam driven rolls, a tachometer is of special value. The speed not only may affect the quality and quantity of the work, but also must be considered in prolonging the usefulness of the machinery. By maintaining a straight line curve on the tachometer record, as high on the chart as good judgment permits, the maximum quantity of work can be produced with little chance of a fly wheel going out through the roof.

Where reversing engines are used, the record may be even more important. The electric type of tachometer, frequently provided for this purpose, has a range of minus 150 r.p.m. to plus 150 r.p.m. with zero, of course, in the center of the strip chart. The recorder may be placed in an office several hundred feet away and an indicator right in front of the operator, to guide him in the manipulation of the levers. A magneto with a very light armature may be installed at the reversing engine and driven by a light web belt, using the engine shaft as a pulley. Chain drives and leather belts are too heavy here.

Master mechanics state that they can tell which operator is handling the levers by the character of the chart record. Moreover, the operator who brings the engine up to highest speed on the reversals is not necessarily the one who turns out the most work.

One rolling mill reports a saving in machinery repairs, made possible by the extensive use of tachometers, so great that we would hesitate to repeat the figures in this paper.

Hot rolls, especially those used in sheet mills, should be brought up to heat rather carefully to prevent cracking and checking. When temperatures during the run exceed perhaps 750°F., this also shortens the life of the rolls. Roll temperatures may be kept down by the liberal use of water where heavy material is run through the rolls, but in

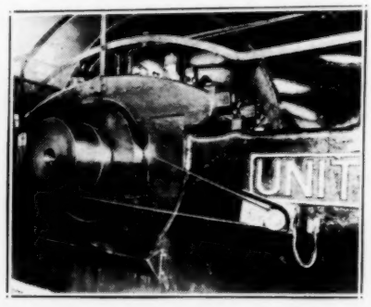


FIG. 8—Tachometer magneto connected with light web belt to drive shaft of reversing engine.

sheet mills the lighter material will not stand so much cooling.

A light portable direct reading pyrometer of rugged construction is frequently used with a special quick reading surface contact thermo-couple. This is of special value at the time the rolls are brought up to heat, but is also used in teaching the men to judge roll temperatures during the run. The couple is made up with a flat thin thermo-junction and protected from the cooling of the air on the side away from the roll.

Structural Steel Plant

The increasing use of arc welding has created a demand for an instrument to record the cycle of operations and give a history of the work done by the welder. A recording shunt ammeter does this so well that it is regularly furnished with some welding machines. It gives a record of time worked by the welder so that the faithful welder gets full credit for his work. At the same time, tricks used by other workmen are exposed on the chart. The character of the curves show the type of work. If a large stick or two sticks are used, instead of one, to rush the work, this is shown up by the excess current. Reversed polarity hastens the work and badly weakens the weld and is unmistakably recorded on the chart. If an electrode is thrown on the ground and left there, the stranght line curve shown on the chart indicates the grounding of the electrode. Reference to the chart is a help to the welder and enables the supervisor to correct any irregularities.

A voltmeter, which records a range as low as a few volts, may also be used to advantage with welding equipment for some kinds of work.

In the structural plant, the air pressure maintained is frequently the cause of dispute and delay. A recording pressure gauge gives a permanent record of the pressure available at all times for the air-operated machinery.

Open Hearth

The checking of operations on the reversing valves on open hearths is considered of the greatest importance in most steel plants. It is essential that the reversing valve be thrown on schedule from one checker work to the other so that each checker may be brought up to the proper heat and fuel not wasted after the checker has absorbed this heat.

A very effective way of checking this operation is to install an electric time recorder on the reversing valve. This time recorder has a pen operated by an electro magnet. This pen is wired to a simple contact on the reversing valve. This contact is so placed that, with the valve in one position, the circuit is open and with the valve in the other position, the circuit is closed. The pen moves over when the valve is in one position and moves back when the valve is reversed. The resulting record shows at a glance the exact time of each reversal.

FIG. 9—Illustrating the application of a quick reading thermo-couple to a hot roll.

The low cost of this instrument and the almost universally recognized need of such a check on operations has resulted in the wide adoption of it on open hearth furnaces.

An electric time recorder with as many as twenty pens to show the time of reversals of twenty valves may be placed right in the open hearth superintendent's office. In addition to this record for the superintendent, one plant uses a single pen recorder right at each valve to guide the operator and indicate to him how the furnace was running during the previous shift. This single pen recorder has a round chart revolving once in 24 hours, but the pen may be shifted into a new position each day so that six or seven days' record are obtained, shown by concentric circles on one chart. Round chart recorders with as many as twelve pens are also used for this application. Recording pressure gauges on gas or oil lines, flow meters or recording draft gauges will also show the time of reversals of valves.

Some tendency has been shown of late to go further than keep a record of the reversing valve operations. It has been felt that automatically controlling these operations, thus removing the human factor, would be a decided step forward and well worth some expenditure of money. This plan also takes into consideration the fact that the checker work at one end of the furnace frequently heats up more slowly than the checkers at the opposite end.

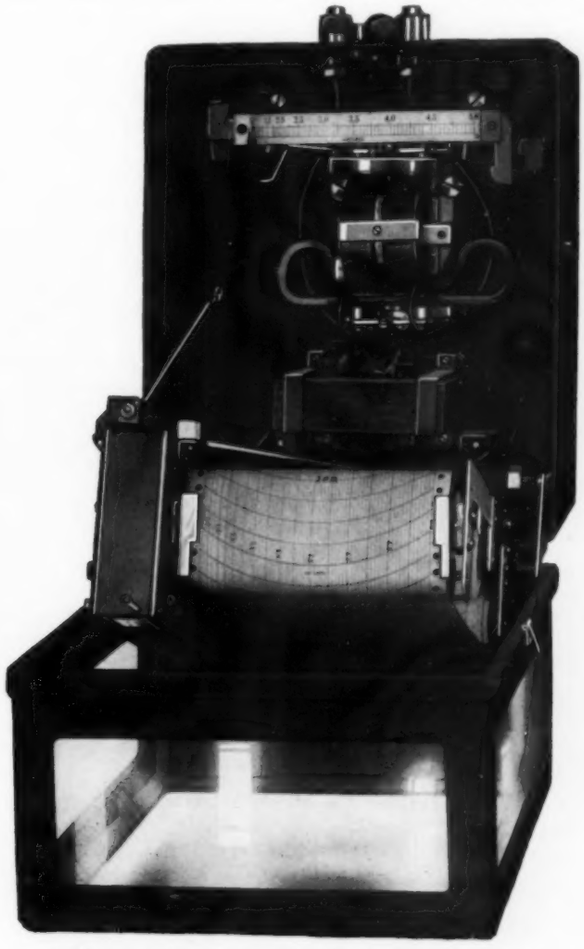


FIG. 10— Ammeter, open to show movement.

A scheme of accomplishing this control has been worked out using two pyrometer controllers. The location of the thermo-couple has been the greatest problem to consider here. If the thermo-couples are located in the hot part of the checker work, the temperatures are so high as to require the use of platinum couples resulting not only in greater initial expense, but also in great care and upkeep of thermo-couples. It has been pretty definitely established that a cooler spot in the rear of the checker work can be located where the changes of temperature are directly proportional to those in the hot zone. This permits the use of base metal couples and results in comparatively little upkeep. Once this cool spot has been located, and the temperature there correspond-

ing to the maximum temperature desired in the checker work determined; the rest is a simple procedure. A thermo-couple is located in each checker work and each couple connected to a pyrometer controller. The spotter on each controller is set at the temperature corresponding to the maximum temperature desired. The two controllers are then wired to the motor over the reversing valve. If checker work A is heating up, as soon as that checker work reaches the desired temperature a contact is closed in controller A which starts the motor of the reversing valve throwing it over to checker work B. Then, as soon as B reaches the desired temperature, a contact is closed in controller B, and the valve is thrown back to A. By means of an automatic reversing switch from the thermo-couples, one controller only will do this work.

A successful installation has been made to control the reversal of valves by a differential temperature. By connecting the two thermo-couples in series and opposed to each other, the control instrument is operated by the difference in the temperatures in the two checker chambers.

Some open hearth departments have found it highly desirable to keep a daily check of temperatures in different parts of the checker work. This gives a valuable line on stoppages of dirt, soot, etc. For this work, a portable indicating pyrometer is used. The usual range is 0 to 2500° F. using a base metal thermo-couple with a nichrome or some other high temperature metallic protection well.

When waste heat boilers are used, a duplex recording pyrometer is desirable to give the temperatures of the gases both entering and leaving the boiler.

On oil fired open hearths, a record of the pressure of both the oil and steam to the burners is considered desirable. This is obtained with a standard recording gauge on the oil line and another on the steam line. The chart ranges are dependent on the pressures used which, of course, vary somewhat with different plants.

Where oil is burned, it is usually preheated. In such cases, a recording thermometer should be installed on the oil line. This gives a check on the oil temperature as it is fed to the burners, insuring proper operating conditions and also giving a check on the efficiency of the oil preheater. Many companies consider this temperature so important, they also install automatic temperature control on the oil heater. Tar, as fuel, makes this instrument equipment even more important.

In cases where producer gas is supplied, there is a marked tendency for the reversing valves to clog up with soot and tar. It is very important to keep these valves clean insuring an open passage for the gas at all times. Of course, as the valve clogs up, it operates with greater difficulty and if electrically operated, the motor on that valve pulls more and more current. Therefore, if a recording ammeter is placed in the circuit to each motor, the record of the amperage each motor is pulling will show an increase as that valve clogs up; and will indicate when that valve should be cleaned.

Soaking Pits

Practically the same instruments listed for the open hearth furnaces can also be used at the soaking pits, although gas is the fuel regularily used. The electric time recorder on the reversing valves is of special importance.

Wire Mill

The temperature of the acid bath, used to clean the hard scale from hot rolled rods and annealed wire, is important. About 180° F., if the acid solution is not too strong, seems to give the quickest action without undue evaporation of acid or pitting of the wire material. A fume proof recording thermometer with lead tubing and bulb is extensively used at pickling vats. The chart range is about 30 to 220° F.

A combination recorder and temperature controller is now on the market which may be connected to the lighting circuit in any plant and operate a motor driven steam valve on the steam line to the pickling vat. This device is extra rugged and avoids the trouble caused by oil and dirt in air and steam lines to the small pilot passages in air and steam operated controllers. The recorder mechanism is entirely independent of the mechanism which operates the control contacts and gives a true record of the temperatures in the bath.

FIG. 11—Rugged type of pyrometer controller for reversing valves on open hearth.

Rods or wire, lime coated for dry drawing, are baked for several hours at temperatures of about 350° F., depending on the materials. Recording thermometers, with a somewhat higher range, are used to record the temperatures and time of the bake. The properly dried lime surface helps to protect the material from oxidation before drawing, neutralizes traces of acid not washed away after pickling and carries the lubricants through the drawing dies.

Recording pyrometers are regularly used for annealing, where rods or wire are treated to soften them or to refine their grain structure. Some annealing processes must be held within close temperature limits and involve a time cycle so that a record is especially desirable.

Where numerous pots are in service, a round chart recorder with a range as high as 1600° F.

placed at each pot is probably the simplest, most rugged instrument. It gives a separate record for each pot which is easy to file and locate when required.

Lead annealing is a good application for the pyrometer temperature controller with electrically operated gas or oil valves. Whatever fuel is used, a recording pyrometer is desirable to record the continuous temperatures maintained.

On the patenting furnace, records of the temperature in the different zones are desirable. A

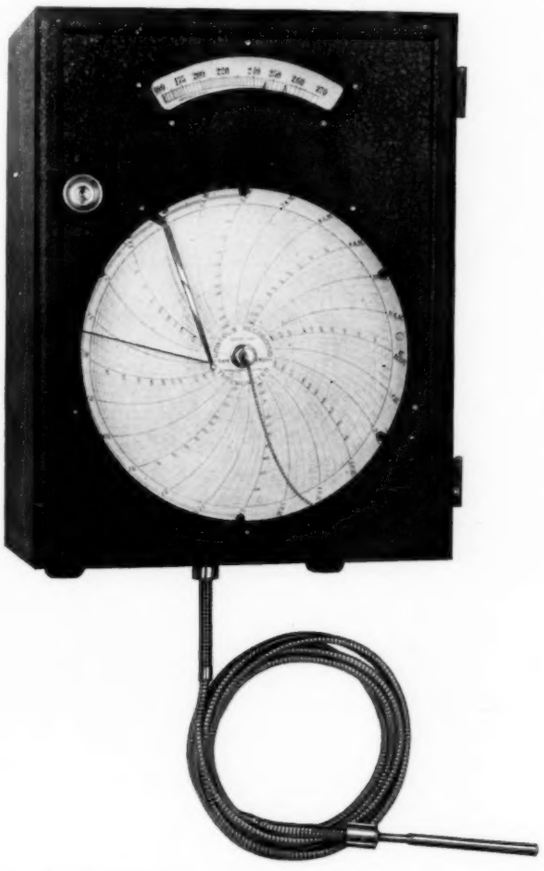


FIG. 12—Combination recorder and controller for use with motor operated steam valve.

pyrometer giving several records on a strip chart adapts itself well to this application. When oil or gas is burned, a pyrometer temperature controller is available to regulate the flow of fuel and air to the burners. A separate controller for each of two zones in the furnace may be used to regulate each of two sets of burners or the temperature may be controlled only in the critical part of the furnace. The temperature of the lead bath, usually at the end of a patenting furnace, is not considered by some so hard to control. A recording pyrometer or one with an indicating scale only may do to guide the operator, although it would be a simple matter to secure the complete automatic temperature control by connecting control instruments to the lead bath at this point.

The galvanizing bath offers one of the best applications in the wire mill for a temperature controller of the thermo electric type, for use with electrically operated control valves for oil or gas fuel. If coal or coke is burned, a recording pyrometer only, with a range of 0 to 1100° F. will be suggested. The controller is being used more often with coke and coal fired equipment to regulate forced draft fans and the draft dampers. Even on coal and coke fired galvanizing pots, controllers may be used in the future.

In order to have a minimum of wire breakage and a maximum life of dies and at the same time get capacity output from the machine, it is necessary to keep a close check on the speed of operation. A recording tachometer offers the best means of doing this. Besides recording the speed at all times, it shows when the machine was shut down and the duration of the lost time. An electric instrument used for this work has a small magneto connected directly to the rotating shaft by a universal joint. The recording instrument is connected to the magneto by duplex copper leads and can be mounted at a considerable distance from the machine if desired. When installed at a distance, an indicating instrument is placed near the machine for the guidance of the operator.

Electrical Department

In the steel mills, electrical equipment is selected extra heavy and rugged to stand up under more severe operating conditions than are encountered in the average manufacturing plant. Recording electrical instruments are available for just such conditions and it is not unusual to find some models which have been in continuous service thirty years or more.

A strip chart wattmeter is desirable for recording the total load in the plant. This record points out the need for more detailed surveys when the efficiency of the plant begins to decrease, as shown by too high a power consumption. It, also, shows any tendency of the different shifts to idle machinery just before noon and before quitting time. Delay in getting machines up to speed when a new shift arrives, adds up to wasted time revealed by this chart.

Another value of the record secured on the recording wattmeter is the information obtained about peak loads. By a careful study of such data, one rolling mill reported that changes were made possible resulting in savings of $2,000.00 per month.

Without sacrificing the rugged features of such a recording wattmeter, it is also made up in a portable carrying case, so that it may be used in testing loads on various distributing lines and on individual motors. Determining the right sized motor for a job naturally results in considerable saving, both in power and equipment. Locating motors which are not functioning satisfactorily and require repairs is also made easy by using such an instrument.

These same wattmeters connected with a phasing transformer may be employed to ascertain the power factor of the plant.

In the steel plant, the round chart recording voltmeter is the type most extensively used. Big rises in voltage during the slack hours of the day result in hot motors and repair costs which can be greatly decreased by proper voltage regulation. Voltmeters on the various distributing lines also furnish indisputable records of shut downs and certain causes for slowing up of machines.

A recording frequency meter, either of the round chart or strip chart type, is desirable on alternating current systems. When the quality of so many products in the steel mill depends on constant speed machinery, the frequency meter is watched carefully. There is, also, a tendency for large plants belonging to the same company to tie together their power lines making uniform frequency even more important. Records of frequency should be on charts with wide open partial scales, with ranges like 20 to 30 cycles or 55 to 65 cycles, so that a fraction of one cycle can be read on the chart.

The recording ammeter, for use with transformers on alternating current and for use with shunts on direct current, will take care of any kind of a load and is quite useful on distributing lines. The instrument is also made for use interchangeably on alternating current and direct current on certain ranges.

No attempt will be made to mention all the instruments handled by the electrical department, as this department has charge of all instruments in some steel mills, besides having to keep in running order about every piece of equipment constructed with even an electric light. But mention will be made of the recording thermometer, with a range of 40 to 600° F., with an iron bulb to go into the armature baking oven. The electric department may wish to have this oven automatic and equip it with a temperature controller to throttle an electrically operated gas valve for the oven. This controller is made with an indicating scale so that the actual oven temperature is shown at all times and so that contact control adjustments may be changed instantly to some new operating temperature if desired.

Laboratory

In the steel mill laboratory, a pyrometer temperature controller with electric contacts for operating relays to the electrically heated oven, releases a valuable man for doing other work while samples being tested are brought up to heat. A pyrometer controller with a range of 2000° F. using a short fire end in a nichrome protection well is ordinarily best suited for this work.

Malleable Iron

Powdered coal is frequently used in the air furnaces for melting cast iron in the malleable iron plant. This seems to be a good place to refer, therefore, to the recording thermometers used on coal dryers. These are made with dust proof cases, range 40 to 800° F., and supplied with a long iron bulb extending through the flue, through which the drying gases pass. This bulb is made up with the sensitive portion half way out on the bulb, to be in the center of the flue. The same bulb is offered with a temperature controller to operate a motor attachment on the dampers.

Optical pyrometers are sometimes used to indicate the roof temperatures in the air furnace during the melt.

Recording pyrometers are applied to give a record of the waste gas temperatures from these air furnaces, if waste heat boilers are used. The duplex pyrometer is well adapted for this, showing incoming and outgoing temperatures as explained under the subject of open hearth instruments. This, of course, involves the other power house recorders.

On the powdered coal fired air furnace, a recording draft gauge to record about 4 in. head of water, forced draft, is important.

When cupalos for melting are employed, the blast pressure is recorded. The practice seems to be to keep this record in ounces of pressure, and a range from 0 to 20 ounces is often selected for the chart. The record is their reference used in maintaining a uniform flow of air, even when voltage fluctuations affect the blower speed.

Instruments mentioned for the open hearth are required in the few installations where a regenerative open hearth furnace is employed for the melt.

FIG. 13—Controller for use on armature baking ovens.

Electric furnaces for melting iron for the malleable plant involve the use of recording wattmeters or ammeters and the use of recording voltmeters. A wattmeter controller to control the power input is also now available.

The malleable annealing furnaces, stoker fired, may use recording tachometers as a guide in securing uniform operating conditions.

When oil, natural gas or producer gas is supplied to the malleable iron air furnace, the same instruments for fuel lines mentioned under the subject of the open hearth are needed.

For malleable iron annealing, a temperature cycle covering a considerable period of time is involved. The furnace temperature and also the temperature inside the annealing box should be known. On account of the large number of boxes to be reached in one furnace, it may be more practical to record furnace temperatures and the temperatures inside of a few boxes, selected to give average conditions. A duplex record pyrometer, recording box and furnace temperatures over the entire annealing period, or a multiple record pyrometer will be satisfactory, with a range of 0 to 2000° F.

There is considerable interest at the present time in the continuous tunnel furnace for large production work. This development will call for pyrometer controllers to regulate the burners of oil or gas. A separate controller for each zone, taking care of its own motor operated valve and burners, will then be

needed just as they are now used on continuous kilns in the ceramic industry.

For the continuous type of annealing furnace, a recording pressure gauge is of value attached to the hydraulic ram pushing the load through the furnace. If this record is watched, there is little chance, after the track is blocked, that the side of the furnace will be pushed out before the trouble is discovered. This recorder is also furnished with an electrical alarm as a warning signal when exeessive pressures are reached.

Foundry

More attention than ever before is now given to the temperature records at core ovens. It is often an expensive matter to burn up a batch of special cores besides the delay to the remainder of the foundry work. Recorders anticipate these high temperatures by showing the rate of change in temperature. The fireman soon learns to shut off the drafts if the record starts going up rapidly. The use of an indicating instrument would not give the same warning as it would be necessary to watch the indicator a while, to determine whether the temperature was rising or falling.

Many core ovens require only a recording thermometer with an ink chart record going up to 800° F. This instrument may be furnished with an alarm or signal light attachment, to warn of excessive temperature. In some of the large steel mill foundries, where core oven temperatures may frequently reach rather high points, it is better to furnish recording pyrometers with a range of 0 to 1100° F.

Temperature controllers are recommended where gas or oil fired or electrical heat is applied. These may be either of the thermo-electric type or actuated by mechanism similar to that in a recording thermometer. Core oven fuel lines, with oil, tar or gas, require the instruments described for fuel lines on open hearth furnaces.

Centrifugal iron pipe casting machines are connected with strip chart tachometers, range 0 to 1500 r.p.m. An indicating instrument is placed near the machine for the guidance of the operator and both indicator and recorder receive their power from a water proof magneto driven by a light web belt. The tachometers make it possible to secure pipe with a uniform thickness. If the pipe is spun too slowly, a warped sided casting is secured. If spun too fast, the pipe will have a wave.

For testing finished cast iron pipe under hydraulic pressure, a strip chart pressure gauge with a range of about 0 to 600 pounds and a fast speed, electrically operated, clock gives a permanent record. Such a recorder is frequently built with a motor to speed up the movement of the chart automatically during the periods that pipes are on the test tables.

Armor Plate Department

In the armor plate department, one recorder of special value has a range of 0 to 1600 pounds, using a round chart. It gives the record of the pressure on the hydraulic shears. This pressure must be maintained to shear the heavy material.

Electric time recorders are used to record on one round chart, the time of operation of six or more presses.

Sheet Mill

Sheets passing through a normalizing furnace are gradually heated up to the temperature of about 1600° F. The different zones of temperature in the furnace are often controlled by pyrometer temperature controllers connected to sets of gas burners. The temperatures in these different zones are recorded on multiple record pyrometers. The actual temperature of the sheets themselves is also sometimes recorded on a pyrometer of the optical type. The record on the instrument board is derived from the optical pyrometer thermo-couple fixture, focused through a hole in the furnace roof on the work passing through the normalizer.

In the box annealing furnace, especially for lighter sheets, thermo-couples are often inserted right in the box with the tip between sheet layers. Furnace temperature and box temperature may be recorded together on a strip duplex pyrometer chart. On account of the few working parts of the instrument and the convenience of filing and handling the records, some plants prefer pyrometers with round charts.

To maintain the best reducing atmosphere in the furnace, or in the boxes while they are cooling, preheated gas is introduced into the furnace chamber of annealing boxes where the sheets are treated. A pyrometer temperature controller with a range of 0 to 1600° F. is an efficient device for securing the degree of preheat desired. The controller regulates the fuel supply under the gas heating cylinders by means of the electrically operated valves previously mentioned in this paper.

The pyrometer temperature controller with electrically operated gas or oil valves is also used to advantage on the sheet reheating furnace. Temperatures in the furnace, of course, must not be run too high, or the sheets will be injured.

Under the subject of the rolling mill, mention was made of the portable pyrometer, which is an aid in the hot roll department for bringing rolls up to heat and keeping temperatures below the harmful point.

Temperature recorders and controllers on the sheet pickling baths are identical with those described for wire pickling baths and usually operate at about the same working ranges.

In the warehouse, where sheets are stored, considerable expense is caused by the rusting of the sheets, including those right in the center of a pile. This condition may be guarded against by reference to a recording psychrometer. This recorder is supplied with a small motor and fan to assure circulation of air over the wet bulb. The range of about 30 to 110° F. is satisfactory. If the record shows the atmospheric condition when dew will form, fans are started up throughout the warehouse, to prevent moisture collecting on the sheets by circulating warm air.

Recording pyrometers are quite generally used on sheet galvanizing baths. The tip of the thermocouple is placed in the part of the bath through which the sheets pass and the instrument records the working temperature of about 830° F. on a chart with a range of 0 to 1100° F.

On gas and oil fired galvanizing pots, temperature controllers can be used successfully. They are needed especially to compensate for changes in the speed at which material is passed through the bath, and to throttle down the electrically operated fuel valves when the machine, moving sheets through the bath, shuts down. The lower part of the bath may be 30° higher than the zone through which the sheets pass. Consequently, the bath temperature rises quickly throughout during a shut down, if the fuel valves are not adjusted. Thermo-couples connected in parallel and located in hot and cool zones, have been used on pyrometer temperature controllers, with encouraging results, to anticipate temperature changes in the galvanizing baths. One couple may be located in the fire box and one in the bath to secure this result.

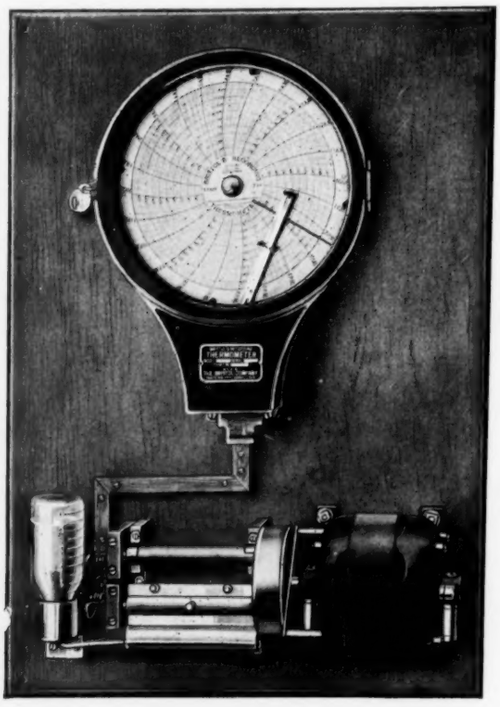


FIG. 14—Psychrometer to protect sheets in warehouse.

For electro-plating, recording ammeters are available to record the current drawn and the time of plating. Where the time of plating only is required, one chart may be used to record the time of operation in several vats. The pens on this chart are actuated by small electro magnets.

Low voltage recording voltmeters are also offered for use in the d-c. generating station of the electro-plating plant.

Instruments on the tin pot consist of a pyrometer or thermometer-controller, to operate valves on the fuel line to the tin pot, and a two pen recording thermometer, to record the temperature of the tin and also the temperature of the palm oil, on the same chart. To secure the clean uniform coating of tin, it is important to control the palm oil temperature as well as that of the tin. Too low a temperature in the palm oil may result in unevenness of the tin on the sheet, as the rolls will not spread the congealing tin properly or roll off excess metal. Too high temperature of the palm oil results in a discolored product.

The palm oil floats on one section of the tin bath and is usually held at a temperature about 470° F. and the tin is held at about 650° F. Practice varies somewhat in different tin mills. Water dripping through a pipe, the outside surface of which is exposed to the oil bath, serves to keep down the palm oil temperature. This is an easy application for a temperature controller of the thermometer type with a little solenoid valve on the water line. Fresh palm oil may also be added to the bath as the cooling medium.

Steel Tubing

In making pipes of steel, many of the same instrument applications are involved that have already been described.

The large annealing furnaces require the same types of recording pyrometers, temperature controllers and control valves as used in other parts of the steel mill. A multiple record pyrometer to record temperatures in several parts of a pipe annealing furnace is desirable.

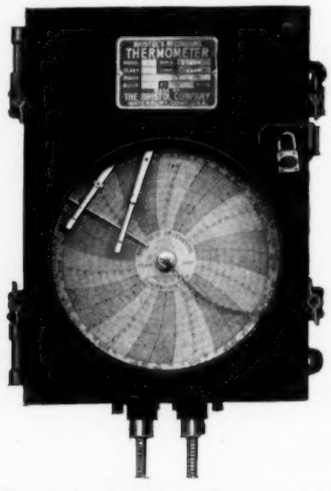


FIG. 15—Two pen thermometer to record temperatures of tin and palm oil.

Temperature control equipment for regulating the fuel and air to the burners may be offered in several units each consisting of a pyrometer controller and electrically operated gas and air valves, or oil and air valves. The temperature in more than one section of the furnace is then subject to this automatic control.

Recording pyrometers on lap welding and butt welding furnaces are desirable for securing uniform operating conditions, as a matter of fuel economy and as a guide in protecting the furnace lining. On account of the high temperatures in welding furnaces, thermo-couples have been inserted part way into the brick work in the crown of the furnace. The resulting record gives a relative temperature, below the actual furnace temperature. It enables the operators to duplicate desirable heating conditions from day to day and, at the same time, use only inexpensive base metal thermo-couples.

The problem of recording temperatures in the bending furnace is easier. Fuel economy is the main reason for such a record.

Pipe pickling bath temperatures may be regulated with a combination recorder and temperature controller as described under the heading "Wire Mills." The big motor operated steam valve is of a special help in this instance, to take care of the sudden fluctuations of temperature when a batch of pipe is lowered into the pickle bath. The control valve may be placed on a live steam line to supplement the supply of exhaust steam constantly flowing into the pickle bath. Or it is practical to supply control valves on both an exhaust steam line and a live steam line. The controller can be arranged to open the live steam valve only when the exhaust steam supply is not sufficient to bring the bath up to temperature.

On the pipe galvanizing bath the temperature recorder and controller are also desirable. The recorder shows that the desired temperatures are maintained and that the pipes are left in the bath the proper length of time to come up to the temperature of the spelter.

FIG. 16—Motor operated tseam valve for use on steam line to pickling bath.

The controller on oil or gas fired galvanizing baths is arranged to function instantly when a mass of cool material is dipped into the bath. The instrument used is described under the headings of wire mills and of sheet mills.

Where a tar like paint or coating is applied to pipe, the temperature of the bath may be recorded in ink with a thermometer having a range of about 30 to 400° F. The temperature of the mixture may also be adjusted by means of the thermometer controller to which this article has frequently referred.

Tachometers are of value when steel pipe is lined with an asphalt mixture, as a uniform coating is more easily secured when the pipe is spun at a predetermined speed.

The special strip chart recording gauge previously mentioned for testing cast iron pipe is also used for testing steel pipe. The pressures are considerably higher and may require charts with a range of 0 to 2000 pounds or more.

In closing it may be well to suggest that there is no other apparatus which returns so much on the investment as an instrument, selected properly, installed properly and cared for properly.

To get 100% efficiency from the instrument it must be selected with the right thermocouple or bulb, the right length of lead, and the right range. Accuracy of the readings, under the severe operating conditions usually encountered in a steel mill, is the prime requisite. To secure this continuous accuracy, select an instrument with the fewest possible working parts to corrode and to wear. Links, levers, pivots and multiplying devices in the instrument mechanism may be necessary evils sometimes, but should be avoided whenever possible. They are certainly sources of friction and not to be lauded as so called improvements. Then select models with protection cases suitable for the surrounding. Heavy cast iron cases are out of place on a fine switchboard, but are ideal in a room filled with gas or acid fumes. Mount your instrument where it will be subjected to the least amount of vibration. Instruments are made to stand the vibration right in the cab of a steam locomotive, but there is no reason for reducing the length of their life by such treatment unless it is necessary. If the recorder contains a delicate electrical movement and is located where heavy deposits of dust collect, an extra protection case should be provided to prevent this dust from falling inside the instrument, when it is necessary to open the door to change the chart.

Appoint one man to change the charts, ink the pen and wind the clock. If everyone in the department has access to the case and tries to make adjustments to suit his fancy, the record loses its value.

It seems to be the custom in some plants to select instruments for a new installation after all other equipment has been chosen and possibly after the other equipment has been put into service. This delay is poor judgment. The very time your new apparatus most needs the protection and the guidance offered by the instrument is when this apparatus is first put in operation.

While in attendance at the Convention and Exposition, your committee would appreciate it if you would arrange to attend the luncheons scheduled for Monday, Tuesday and Wednesday, June 25th, 26th and 27th. Special features have been arranged for the luncheons on these three days.

*Discussion of the Elements Entering Into the Cost of Producing Power**

By W. B. SKINKLE†

COSTS are a sort of mythical something that everybody is always talking about and which few really understand. They are a critical element in a highly competitive business over which both engineers and business men successfully "kid" themselves into the belief that they are making or losing money. It is seldom that two organizations look at costs from the same view point, yet we are always trying to compare figures founded on different bases, and wondering at the differences.

Costs from a strictly clerical view-point are of little assistance to the engineer, yet the engineer is constantly using these "clerical costs" to form the basis for future operations or from which to figure savings that will accrue under an altered set of working conditions which he proposes to place in operation. In this paper, an analysis is undertaken of the elements entering into the cost of the production of steam and electric energy and an attempt is made to place these elements in what might be termed an engineering conception of their proper relation to each other.

Most men think of cost in terms of "a unit of product;" speaking electrically they think of, and try to compare, the cost per kw. hr.

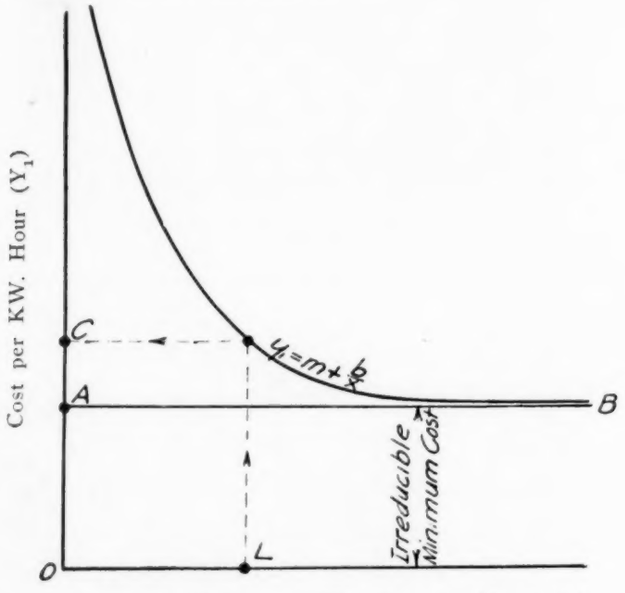


FIG. 1.

Take for example any comparatively large turbo-generator and plot the cost per kw. hr. against load factor, or what is preferable the kw. hrs. produced in a unit of time, and we get the old familiar curve like Fig. 1, where the cost per unit of product is continually dropping as the number of kw. hrs. produced increases; the lowering costs per kw. hr. approaching an irreducible minimum that it never quite succeeds in reaching. This irreducible minimum cost is represented by the line "AB" and may represent the cost of fuel, some labor, fixed charges, charges, etc.

Thinking of this curve from a purely mathematical standpoint, we are at once struck with its similarity to the definition of an hyperbola, which is a curved line that continually approaches a straight line called the asymptote, but which it never reaches at any distance short of infinity. Such a curve has the general form of $y = m + \frac{b}{x}$.

If we wanted the total cost of operating a power house which was producing OL kw. hrs., we would multiply the kw. hrs. produced (OL) by the cost per kw. hr., (OC), and the result should equal the total money as shown on the cost sheet. Let us do the same thing with the general equation of our hyperbolic curve, in other words, get a new total cost "y" by multiplying y_1 by x, or expressed algebraically

$$y = xy_1 \quad \ldots\ldots (1)$$

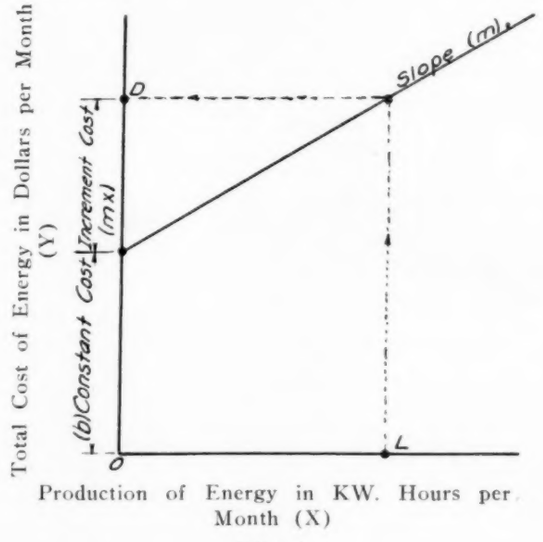


FIG. 2.

On looking at the general equation, we find that

$$y_1 = m + \frac{b}{x}$$

and substituting this, we have

$$y = x(m + \frac{b}{x}),$$

which when simplified gives us

$$y = mx + b \quad \ldots\ldots (2)$$

*To be presented before AI&SEE Annual Convention, June 25th,-28th, 1928.

†Engineer, Pittsburgh District Power Committee, Subsidiary Companies of United States Steel Corporation.

This equation is the well known straight line and will take the form of Fig. 2, in which

x = the production of energy in kw. hrs. per month (OL)

y = total cost of energy in dollars per month (OD)

b = a constant cost which is independent of the production (X)

m, (which is the slope of the line) = an "increment" cost per unit of product, which is directly proportional to the quantity of energy produced.

In other words, a production of energy x equal to the horizontal distance "OL" would give a cost y equal to the vertical distance "OD", which cost would be made up of the sum of a constant cost "b" plus an increment cost "mx".

Before attempting to apply this purely theoretical analysis to actual cost sheets, it may be well to establish some fundamental definitions of various kinds of costs, so that in later discussion of the subject, confusion will be avoided.

Terms as defined will be made in the following discussion:

DEFINITIONS:

Total Cost (T_c) is the cost of producing steam or electric energy including fixed charges on the investment, turbine room costs, costs of steam (above fuel), and cost of fuel.

Operating cost (O_c) is the cost of producing steam or electric energy as shown on the cost sheets. This includes turbine room costs, cost of steam (above fuel), and cost of fuel, but is exclusive of all fixed charges resulting from the original cost of the equipment.

The Increment Cost (I_c) is the cost of producing an additional increment of energy when the equipment under consideration is already carrying a given load, which is below its maximum permissible load, and it is desired to increase this load. For example, a 15,000 kw. generator may be producing 5,500,000 kw. hrs. per month at an operating cost of $24,000 per month. It seems desirable to increase the output to 7,000,000 kw. hrs. per month at a producing cost of $28,000 per month. The increment load would be 1,500,000 kw. hrs. per month; the increment operating cost would be $28,000 — $24,000 = $4,000 per month and the increment cost per kw. hr. would be $\frac{4,000.00}{1,500,000} = 2.66$ mills, as against an original average cost of $\frac{24,000.00}{5,500,000} = 4.37$ mills per kw. hr.

Fixed charges are those resulting from the original investment. In this Study they are taken as 13% subdivided as follows: 6% interest on investment, 5% depreciation and 2% for insurance and taxes.

The Turbine Room Cost is that part of the expense, (exclusive of steam), that is directly connected with operating the turbo-generator or its immediate auxiliaries. The Cost of Steam may be subdivided into two items, viz: "Cost of Fuel" and "Cost Above Fuel."

In analyzing the cost of steam or electric energy at a power house switchboard, from existing cost sheets, it is somewhat difficult to interpret the data, shift the factors to another set of conditions and expect to get reasonably accurate results.

The present analysis attempts to explain this apparent source of error and to place the data in such shape that the factors may be shifted to any desired set of conditions and the expected costs due to these changes of conditions forecasted with reasonable accuracy.

COST:

The total cost of any product is represented by the sum of the fixed charges plus the operating costs. The fixed charges are constant and independent of the production. The operating costs are variable and largely dependent on the output. There is, however, a large part of the operating cost which is constant regardless of the output, and in addition an "Increment Cost" which is directly proportional to the output. The segregation of that part of the operating cost which is "constant" and the determination of the "Increment Cost" is the major object of the following discussion.

In examining the itemized cost sheet on the production of steam or electric energy, it is easily seen that certain items are constant regardless of the load on the power station, as for example: "Superintendence. Repairs on Buildings and Roofs," etc. Other items at first thought appear to be variable in direct proportion to the load. Careful consideration of these last items, however, failed to disclose a single item that did not have a "Constant" element which was independent of the load.

In attempting to segregate the elements of constant and variable costs, in the following items, the opinions of a number of power engineers were obtained, each engineer basing his opinion solely upon his own judgment independent of the opinions of others. The combined opinions were then discussed individually with the several men consulted and their original estimates revised, giving due consideration to the opinions of others. An average was then taken of the revised opinions of the several men consulted after discussing the items in detail.

STEAM COSTS, (BLAST FCE. GAS FIRED BOILERS)

Producing Labor:

Superintendence:

The cost of superintendence being independent of the quantity of steam produced, this item was charged as being 0% variable and 100% constant.

1—Unloading Fuel for Immediate Use.

2—Delivery, (Stock Pile to Boilers).

3—Crushing.

4—Delivery, (Crusher to Hopper).

The cost sheet is designed to cover both coal and blast furnace gas-fired boilers. In blast furnace gas-fired boilers, the items chargeable to these sub-accounts will be very small. They have been considered as 10% variable and 90% constant.

Firemen:

If the boilers are hot, firemen must be on duty. This item is, therefore, considered 0% variable and 100% constant.

Labor for Ash Disposal:

This item is considered 0% variable and 100% constant.

Water Tenders:

This item was considered as 0% variable and 100% constant.

Boiler Washers and Cleaners:

If the boilers are being operated at high ratings, they are evaporating more water and burning more fuel and would, therefore, need cleaning more often than if they were operated at lower ratings. This item has, therefore, been considered as 50% variable and 50% constant.

All Other Producing Labor:

This item was considered 0% variable and 100% constant.

Repairs and Maintenance:

Stokers, Grates, Burners, Etc.:

This item was considered as 50% variable and 50% constant.

Boilers and Fittings:

This item was considered as 50% variable and 50% constant.

Boiler Settings:

This item was considered 50% variable and 50% constant.

Steam Mains and Pipe Coverings:

It is believed that item will be constant regardless of the quantity of steam being passed through the lines and was, therefore, charged as 0% variable and 100% constant.

All Other Repairs and Maintenance:

This item was considered as 10% variable and 90% constant.

Miscellaneous Expense:

1—**Tools, Lubricants, etc.**
2—**Water, (Exclusive of Feedwater).**
3—**Electric Current, (Exclusive of Auxiliaries).**
4—**Yard Switching.**
5—**Laboratory Expense.**
6—**Shop Expense.**
7—**Accident and Hospital Expense.**

These items represent miscellaneous expense in the Plant which cannot be charged to particular Departments and are, therefore, absorbed by general distribution. They will be constant regardless of the load and are all charged as 0% variable and 100% constant.

Total Cost of Water Purification:

The chief expense in this item is the cost of chemicals and the cost of pumping the water. These are directly proportional to the quantity of water treated. The labor and maintenance on the water purifying plant are constant regardless of the quantity of water purified. For these reasons 75% of this item is considered variable and 25% constant.

Cost of Fuel per Bo. H.P. Month:

This item is almost directly proportional to the load. There are, however, certain items such as radiation losses, unburned fuel, etc., which will be constant regardless of the load. The item is, therefore, charged as 90% variable and 10% constant.

The foregoing items are tabulated on the following page, Table No. 1, which is used as a basis for the Graph. This Graph uses as the vertical ordinate the "cost of operating a steam boiler plant in "dollars per month" and the horizontal ordinate the "Steam produced in Boiler Horse Power Months per Month." The graph is subdivided to show the portion of the total cost which is constant regardless of the load and the Increment Cost which is directly proportional to the load. It is further sub-divided to show Fixed Charges, Cost of Steam Exclusive of Fuel and Cost of Fuel.

Calculations Forming Basis for Graphic Chart Titled "Cost of Producing Steam in a Hypothetical Boiler House of 15,000 Bo. H.P. Installed Capacity:"

General practice indicates that approximately 133% is the average annual rating of Steel Works Boilers. The output of this boiler house would, therefore, be

Rated Capacity		Percent of Rating		
15,000	×	1.33	=	20,000 Bo. HP. Mos. per Mo.

Estimates of the cost of a modern boiler house indicate that $123 per Hp. of rated capacity would be a fair price on which to base fixed charges.

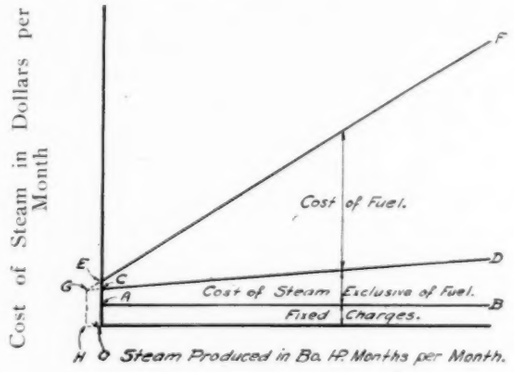
	Cost per rated Hp.		Hp. installed		Investment
Cost of Bo. House =	123	×	15,000	=	$1,850,000

	Investment		Fixed charge rate		
Fixed charges =	1,850,000	×	.13	=	$240,000 per year.

Monthly Cost of Fixed charges at 13% =

Fixed chgs. per year		Mo. per year		Fixed chgs. per month
240,000	÷	12	=	$20,000

This fixed charge of $20,000 per month is constant regardless of the production of steam and is shown on Fig. 3 as the line AB.



Steam Produced in Bo. HP. Months per Month.

FIG. 3

Steam Costs:

On line 24, column 6, Table No. 1, the constant cost of steam, **exclusive of fuel,** is shown as $0.934 per Bo. Hp. Mo.

The production of steam is 20,000 Bo. Hp. Mo. per Mo. Therefore, the constant monthly cost of steam, **exclusive of fuel,** is

Constant per bo. hp. mo.		Bo. hp. mo. per month		Constant cost
.934	×	20,000	=	$18,700

This represents a constant expense in the boiler house, (exclusive of fuel), which is independent of the steam produced. This is shown by the vertical height AC of Fig. 3.

COST OF PRODUCING STEAM
HYPOTHETICAL BOILER HOUSE OF 15,000 BO. H. P. CAPACITY
TABULATION SHOWING METHOD OF SEPARATING CONSTANT AND VARIABLE ITEMS
TABLE NO. 1

Col. No.	1	2	3	4	5	6
Line No.		Cost in %		Cost per Bo. Hp. Mo.		
	Item	Variable	Constant	P.F. Gas	Variable	Constant
1	**Producing Labor** Superintendence	0	100%	.070	-	.070
2	Unloading fuel for immediate use	10%	90%	.050	.005	.045
3	Delivery (stock pile to boilers)					
4	Crushing					
5	Delivery (crusher to hopper)					
6	Firemen	0	100%	.044	-	.044
7	Labor for ash disposal	0	100%	.020	-	.020
8	Water tenders	0	100%	.045	-	.045
9	Boiler washers and cleaners	50%	50%	.030	.015	.015
10	All other producing labor	0	100%	.030	-	.030
11	**Repairs and Maintenance** Stokers, grates, burners, etc.	50%	50%	.066	.033	.033
12	Boilers and fittings	50%	50%	.280	.140	.140
13	Boiler settings	50%	50%	.080	.040	.040
14	Steam mains and pipe coverings	0	100%	.020	-	.020
15	All other repairs & maintenance	10%	90%	.130	.013	.117
16	**Miscellaneous Expense** Tools, lubricants, etc.	0	100%	.080	-	.080
17	Water, (exclusive of feedwater)	0	100%	.020	-	.020
18	Elec. current, (excl. of auxiliaries)	0	100%	.050	-	.050
19	Yard switching	0	100%	.030	-	.030
20	Laboratory expense	0	100%	.015	-	.015
21	Shop expense	0	100%	.050	-	.050
22	Accident and hospital fund	0	100%	.020	-	.020
23	Total Water Purification Cost	75%	25%	.200	.150	.050
24	*Cost per Bo. Hp. Mo. (Exclusive of fuel)*	30% *	70% *	1.330	.396	.934
25	*Cost of fuel per bo. hp. mo.*	90%	10%	3.670	3.303	.367
26	*GRAND TOTAL HYPOTHETICAL COST OF STEAM PER BO. HP. MO.*	74% *	26% *	5.00	3.699	1.301

*Calculated values.

Fuel used per boiler hp.month = $\frac{33,479 \times 730}{13,000 \times .8 \times 8,240} = 1.05$ tons.

Cost of fuel per bo.hp.mo. assuming coal at $3.50 per gross ton } = 3.50 × 1.05 = $3.67

The variable cost, **exclusive of fuel,** is shown on line 24, Col. 5, of Table No. 1, as $0.396 per bo. hp. mo.

An equation may be written for the operating cost, (exclusive of fuel), as follows:

$$O_e \text{ (exc. of fuel)} = \underset{\text{Variable Cost}}{18{,}700} + \underset{\text{Constant cost}}{0.396\ S}$$ where

S = steam produced in Bo. Hp. Mo. per Mo.

The equation for the total cost, (exclusive of fuel), may be written

T_e (excl. of fuel) =

Fixed Charges	Constant Operating Cost	Variable Cost	Constant Cost	Variable Cost
20,000	+ 18,700	+ 0.396 S	= 38,700	+ 0.396 S

This is shown by line CD of Fig. 3.

The constant operating costs per Boiler Horsepower Month, including fuel, as shown on Col. 6, line 26, of Table No. 1, is $1.301. The total production of steam is 20,000 Bo. Hp. Mo. per Mo. Therefore, the constant monthly cost of steam is

Constant Cost per Bo. Hp. Mo.		Bo. Hp. Mo. per Mo.		Constant Cost of Steam per Month
1.301	×	20,000	=	$26,000

This represents a constant operating expense in the boiler house which, (as long as the boilers are kept hot), is independent of the steam produced. In Fig. 3, it is represented by the vertical height AE. The variable Operating Cost is shown on line 26, Col. 5, of Table No. 1, as $3.699 per Bo. Hp. Mo., which in the future calculations will be valued at $3.70. An equation may be written for the operating cost as follows:

$$O_e = \underset{\text{Constant Cost}}{26{,}000} + \underset{\text{Variable Cost}}{3.70\ S} \quad \text{where} \ldots\ldots\ldots (3)$$

S = steam produced in Bo. Hp. Mo. per Mo.

The equation for the total cost of steam may be written

$$T_e = \underset{\text{Fixed charges}}{20{,}000} + \underset{\text{Constant operating cost}}{26{,}000} + \underset{\text{Variable Cost}}{3.70\ S} \quad \text{or}$$

$$T_e = \underset{\text{Constant Cost}}{46{,}000} + \underset{\text{Variable Cost}}{3.70\ S} \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

This is shown by line EF of Fig. 3.

The foregoing equations, and graph show either the total cost "T_e" or the operating costs "O_e" of a particular boiler house which assumes a specific boiler efficiency and a specific cost of fuel per gross ton.

It is obvious that a change in fuel costs will not change the fixed charges or the cost of steam exclusive of fuel. It is equally obvious that a change in the cost of fuel will, therefore, affect only the position and slope of the line EF of Fig. 3. If the cost of fuel rises, this line EF would be higher; if the cost of fuel lowers the result would be a drop in the position and slope of the line EF. A general equation may be written which takes the cost of fuel into consideration. This equation, however, must be written in such form that when the cost of fuel becomes zero, the line EF should fall on and coincide with the line CD. Examination of the graph, Fig. 3, readily discloses that in order to accomplish this result, the equation must be written in such form that the line EF must "hinge" or rotate about the point of intersection of lines EF and CD which is shown as the point G. The equation (4) as already written, viz:

$$T_e = \underset{\text{Constant Cost}}{46{,}000} + \underset{\text{Variable Cost}}{3.70\ S}$$ may be re-written in the following form:

$$T_e = 37{,}850 + (.396 + .945P)\ (S + 2200) \ldots\ldots\ldots (5)$$

without changing its value

where P = cost of coal in dollars per gross ton and

S = steam produced in Bo. Hp. Mos. per Mo.

In this equation, the constant 37,850 represents the vertical height HG. The second constant, viz: .396 represents the **slope** of line CD. The next quantity .945 P brings in the price of coal and is obtained by subtracting the slope of CD (.396) from the slope of EF (3.70) and dividing the remainder by the price of coal on which the graph was based, (viz 3.50), thus 3.70 — .396 = 3.304 and 3.304 ÷ 3.50 = .945 or the value 3.304 = .945 P.

In the next expression, viz: (S + 2200), the symbol "S" represents the quantity of steam produced and the constant (2200) represents the horizontal distance "OH" on the graph.

The general equation as so far developed allows for variations in the price of coal, but requires a constant maintenance of the assumed boiler efficiency, viz: 80%.

The equation can be made completely general for a given boiler house by adding a value for boiler efficiency. A change in boiler efficiency is equivalent to a change in price of coal in the inverse proportion. Thus the fuel cost for this boiler house would be the same for $3.50 coal and 40% efficient boilers or for $7.00 coal and 80% efficient boilers. The general equation can, therefore, be written

$$T_e = 37{,}850 + (.396 + .945\ P\ \frac{.80}{E})\ (S + 2200) \quad (6)$$

Where P = price of coal in dollars per gross ton.

E = the boiler and grate efficiency expressed as a decimal.

S = quantity of steam produced in boiler hp. mo. per month.

This general equation is shown on the graphic chart accompanying the paper, which is so arranged that the line EF of Fig. 3, showing the total cost of steam may be shifted or revolved about the point G, so that it will take care of any change in the price of coal from zero to $7.50 per gross ton or any change in boiler efficiency from 50% to 100%. Instructions for use appear on the face of the chart.

COST OF PRODUCING ELECTRIC ENERGY

The cost of producing electric energy is developed along similar lines to those followed in arriving at the cost of steam.

Taking up the various items in detail, the following opinions on constant and variable percentages were developed.

ELECTRIC COSTS

Producing Labor:

Superintendence:

It was the unanimous opinion that the cost of superintendence in a power station is independent of the load and should, therefore, be charged as 0% variable and 100% constant.

Engineers, Oilers, Wipers, Etc.:

It was the universal opinion that as soon as a turbine started to rotate, a full crew of operators

would be necessary regardless of the load. This item of cost should, therefore, be charged as 0% variable and 100% constant.

Repairs and Maintenance:

Buildings and Roofs:

Repairs on buildings and roofs were charged as 0% variable and 100% constant regardless of the load on the turbine.

Turbine and Auxiliaries:

Considerable diversity of opinion existed regarding the percentage division between the variable and constant cost of this item. It was, however, decided that practically the only difference between quarter load and full load on the turbine would be the torque in the main shaft and the wear on the nozzles and buckets of the turbine. This item was, therefore, charged as 25% variable and 75% constant.

Generators and Switchboards:

For practically the same reasons as given for the item above, it was decided that 25% of the cost of repairs is variable and 75% is constant.

Cranes and Miscellaneous Machinery:

These items were considered constant regardless of the load and were, therefore, charged as 0% variable and 100% constant.

Lubricants, Waste and Packing, Tools, Miscellaneous General Supplies:

The total cost of these items is small and it was finally considered that they would be somewhere near 10% to 12% variable and 88% to 90% constant.

Incidentals:

Yards and Switches, Laboratory Expense, Automobile Trucks, General Shop Expense, Accident and Hospital Fund, Miscellaneous Lost Steam, Etc.:

The total cost of these items is small. They represent miscellaneous expenses in a plant which cannot be charged to particular plant departments or shops and are absorbed by general distribution. They will, therefore, be constant regardless of the load and are charged as 0% variable and 100% constant.

Condenser Water:

There is more variation in the cost of this item than almost any other element entering the cost of electric power. Some part of this variation seems to be chargeable to local conditions existing at the plant under consideration. A great part of the variation seems to be due to methods of accounting. For exemple, some of the stations consider that water, as water, costs nothing. It flows into the intake and, after passing through the condenser, is discharged from the sewer. Following this line of reasoning, the only cost for water is the cost of pumping and repairs on the pumps. In many cases, the cost of pumping water is charged entirely to the item of turbine auxiliaries and only the cost of repairs to the pumps and pipe lines appears on the cost sheets. At other works the entire cost of power, repairs, etc., is charged to the condenser water, even though the tail water from the condensers may be used for other plant purposes. Again, we find the tail water from condensers used for blast furnace cooling, and sometimes the waste from blast furnace cooling used for condensers, in which case almost the entire cost of both pumping and maintenance has been charged against the blast furnaces.

Investigation at the various plants developed that the usual practice is to start the condenser pumps with the valves wide open and let a constant quantity of water into the condenser regardless of the load. This item was, therefore, charged as 0% variable and 100% constant.

Steam:

The cost of steam used in a power house can be subdivided: First: into cost above fuel, and Second: cost of fuel. Each of these items in turn can be divided into steam used by main unit and steam used by auxiliaries.

Steam Exclusive of Fuel:

A tabulation of the cost of steam made along similar lines to the tabulation of costs of electric energy shows that a very large part of the boiler house expense over and above fuel is constant, regardless of production. For this reason, 30% of the "cost above" was considered variable and 70% of the "cost above" was considered constant.

Fuel Used for Steam:

The total steam consumption of a 15,000 kw. unit was plotted against variable load between 5,000 and 15,000 kw. and the line extrapolated to zero, see Fig. 4, where it was found that the turbine would consume approximately 12,000 lbs. steam per hour

STUDY OF COST OF PRODUCING ELECTRIC POWER

Steam Consumption of 15,000 Kw. Turbo Generator

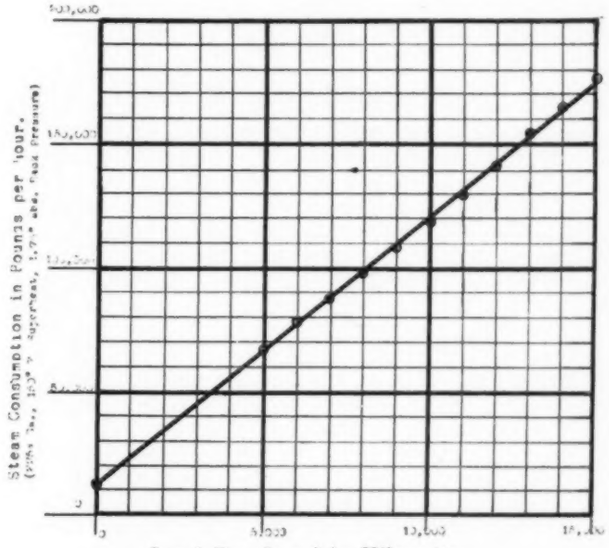


FIG. 4

Let S = Steam consumed in pounds per hour.
E = Load on turbine in Kw. (Kw. hours per hour.)
Then S = 12,000 + 10.6E.

Assuming an average load on the turbine of 10,000 kw., then the steam consumed (exclusive of line and trap losses) is equal to

$\frac{12,000}{120,000}$ = 10% consant. Adding to this 3% for line, trap and other losses, the constant steam consumption equals 10% + 3% = 13% and the variable steam consumption equals 100% — 13% = 87%

at theoretical no load condition. At 10,000 kw. production, the turbine would consume 120,000 lbs. of steam per hour and the 10,000 kw. load was considered an average condition. For this reason, 10% of the steam consumed by the turbine will be constant regardless of the load and 90% of the steam would vary in direct proportion to the load. Line and trap losses, however, are omitted from the foregoing assumptions. Assuming further that a 3% line and trap loss would be constant, the final values of this item were given as 87% variable and 13% constant.

Fuel for Steam to Auxiliaries:

In general, if steam consuming units are used around a power house for the purpose of securing exhaust steam for heating feedwater, these units are of a small and rather inefficient type and consume relatively large quantities of steam regardless of the load. After considerable discussion, it was decided to charge 50% of the fuel to generate this steam as a variable and 50% as constant regardless of the load. Table No. 2 summarizing the foregoing items is attached. In column 2 of this tabulation is shown the cost of the various items per 1,000 kw. hours, which make up the cost of a purely hypothetical 15,000 kw. unit. Repairs are frequently charged into the month when the repairs are made, thus making the cost of this item very erratic on the monthly cost sheets. Therefore, the annual cost of repairs was used instead of an average of several monthly costs.

The charge for condenser water shown in the tabulation was arbitrarily assumed for a hypothetical plant. The experience gained in arriving at these percentages and amounts has shown clearly that a great diversity of opinion will exist among engineers, who may make future use of this method. However, any diversity of opinion while lowering certain items, will raise other items, and the net results will not be radically different from the one which is presented herewith.

The foregoing items are tabulated on the following page, which tabulation is used as a basis for the graphic chart showing Cost of Electric Energy. This graph uses as the vertical ordinate the "cost of producing electric energy in dollars per month," and as a horizontal ordinate the "electric energy produced in kw. hrs. per month." The graph is subdivided to show the portion of the total cost which is constant regardless of the load and the increment cost, which is directly proportional to the load. It is further subdivided to show fixed charges, turbine room costs, cost of steam exclusive of fuel and cost of fuel.

Calculations Forming Basis for Graphic Chart, Titled "Cost of Producing Electric Energy by Hypothetical 15,000 KW. Turbo Generator:"

Estimates on a modern 15,000 kw. turbo-generator station, including boilers, turbo-generator, switchboard, proper housing for equipment and all auxiliaries show that it should cost very close to $1,480,000, which is approximately $100.00 per rated kilowatt of installed capacity. This would be an equitable cost on which to base fixed charges. The fixed charges at 13% would then be

Investment		Fixed charge rate		
1,480,000	×	.13	= $192,000 per year.	

Monthly fixed charges at 13% =

Annual fixed chgs.		Mo. per yr.		
192,000	÷	12	=	16,000.00

This fixed charge of $16,000 per month would be constant regardless of the production of electric energy and is shown on Fig. 5, as the line AB.

Turbine Room Costs:

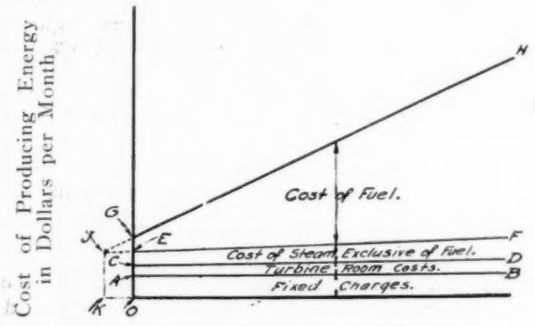
On line 18, Col. 6, Table No. 2, the constant cost of electric energy, **exclusive of steam or fuel,** is shown to be $.652 per 1,000 kw. hrs. This cost, based on a weighted average cost and the corresponding weighted average load factor of 48% over 730 hrs. per month of operation is

Cap. of generator per hour		Hrs. per month		Percent of Capacity Produced		Kw. hrs. produced per month
15,000	×	730	×	.48	=	5,250,000

Therefore, the constant cost of producing electric energy, exclusive **of steam or fuel,** (the turbine room costs), is

Constant cost per 1,000 kw. hrs.		Thousands of kw. hrs. produced per mo.		Constant turbine room cost per mo.
.652	×	5,250	=	$3,425

This represents a constant expense in the turbine room which is independent of the electric energy produced. This is shown by the vertical height AC of Fig. 5.



Electric Energy Produced in KW. Hours per month.

FIG. 5.

The variable cost, (exclusive of steam), is shown on line 18, Col. 5, of the tabulation as $0.000051 per kw. hr. An equation may be written for the operating costs, (exclusive of steam and fuel), as follows:

Constant Cost Variable cost/kw.hr.

O_e (exclusive of steam) = 3,425 + .000051 E where

E = net kw. hrs. of energy produced per month.

The equation for the total cost, **(exclusive of steam or fuel),** may be written T_e (exclusive of steam) =

Fixed chgs.	Constant operating cost	room cost Variable turbine	Constant Cost	Variable turbine room cost
16,000 +	3,425 +	.000051 E =	19,425 +	.000051 E

This is shown by CD of Fig. 5.

The operating costs, **exclusive of fuel,** are shown on line 21 of the tabulation.

Col. 6, line 21, shows the constant operating costs, **exclusive of fuel,** as $1.345 per 1,000 kw. hrs. Therefore, the constant cost of producing electric energy, **exclusive of fuel,** is

Constant cost per 1,000 kw.hrs.		Thousands of kw.hrs. produced per mo.		Constant monthly cost exclu. of fuel
1.345	×	5,250	=	$7,060

This represents a constant expense, (exclusive of fuel), which is independent of the quantity of electric energy produced. This is shown by the vertical height AE of Fig. 5.

COST OF PRODUCING ELECTRIC ENERGY
HYPOTHETICAL GENERATING STATION OF 15,000 KW. INSTALLED CAPACITY
TABULATION SHOWING METHOD OF SEPARATING CONSTANT AND VARIABLE ITEMS
TABLE NO. 2

Col. No.	1	2	3	4	5	6
Line No.	Item	Cost per 1,000 Kw. Hrs.	Cost in percent		Cost per 1,000 Kw. hrs.	
			Variable	Constant	Variable	Constant
1	**Producing Labor**					
	Superintendence	.042	0	100%		.042
2	Engineers, oilers, wipers, etc.	.210	0	100%		.210
3	**Repairs and Maintenance**					
	Buildings and roofs	.019	0	100%		.019
4	Turbines and auxiliaries	.160	25%	75%	.040	.120
5	Generators and switchboards	.040	25%	75%	.010	.030
6	Cranes and miscellaneous machinery	.010	0	100%		.010
7	**Tools, lubricants, misc. sup.**					
	Lubricants	.002	12-1/2	87-1/2		
8	Waste and packing	.002	"	"	.001	.007
9	Tools	.002	"	"		
10	Miscellaneous general supplies	.002	"	"		
11	**Incidentals**					
	Yards and switching					
12	Laboratory expense					
13	Auto trucks	.014	0	100%		.014
14	General shop expense					
15	Accident and hospital fund					
16	Misc. lost steam					
17	**Condenser water**	.200	0	100%		.200
18	*Sub Total*	.703	7%	93%	.051	.652
19	**Steam, exclusive of fuel**					
	Net steam used by turbine	.860	30%	70%	.258	.602
20	Steam used by auxiliaries (15%)	.130	30%	70%	.039	.091
21	*Sub Total*	1.693	20%	80%	.348	1.345
22	**Fuel used for steam**					
	Fuel for net steam to turbine	2.390	87%	13%	2.080	.310
23	Fuel for steam to auxiliaries (15%)	.360	50%	50%	.180	.180
24	*TOTAL*	4.443	59%	41%	2.608	1.835

The variable operating cost, (exclusive of fuel), is shown on line 21, Col. 5, of the tabulation as $0.000348 per kw. hr. An equation may be written for the operating costs, (exclusive of fuel), as follows:

	Constant operating cost		Variable cost per kw. hr.	
O_c (exclusive of fuel) =	7,060	+	.000348	E where

E = net kw. hrs. of energy produced per month.

The equation for total cost, (exclusive of fuel), may be written

T_c (exclu. of fuel), =

Monthly Fixed Charges	Constant Operating Cost		Variable Cost per kw. hr.		Constant Cost		Variable Cost per kw. hr.
16,000	+ 7,060	+	.000348 E	=	23,060	+	.000348 E

This is shown by the line EF of Fig. 5.

The operating costs, (including fuel), are shown on line 24 of the tabulation. Column 6, line 24, shows the constant operating cost, (including fuel), as $1.835 per 1,000 kw. hrs. Therefore, the constant cost of producing electric energy, (including fuel), is

Constant cost per 1,000 kw. hrs.		Thousands of kw. hrs. produced per month		Constant monthly operating cost
1.835	×	5,250	=	$9,650

This represents a constant operating expense which is independent of the quantity of electric energy produced. This is shown by the vertical height AG of Fig. 5. The variable cost, (including fuel), is shown on line 24, Col. 5, of the tabulation as $0.002608 per kw. hr. An equation may be written for the operating costs, (including fuel), as follows:

	Constant operating cost		Variable cost per kw. hr.	
O_c =	9,650	+	.002608	E.....(8)

where E = net kw. hrs. of electric energy produced per month. The equation for the total cost, (including fuel), may be written

	Monthly fixed charges		Constant operating cost		Variable cost per kw. hr.
T_c =	16,000	+	9,650	+	.002608 E

	Constant cost		Variable operating cost	
T_c =	25,650	+	.002608	E .....(9)

This is shown by the line GH of Fig. 5. The foregoing equations and graph show either the total cost "T_c" or the operating cost "O_c" of a particular turbo-generator and assumes a price of fuel, boiler efficiency and a constant production of electric energy from the turbo-generator for a given quantity of steam.

It is obvious that changes in any one of these quantities will change the cost of producing electric energy. It is equally obvious that changes in these variables will not change either fixed charge, turbine room or cost of steam exclusive of fuel. Changes in these variables will, therefore, affect only the position and slope of the line GH of Fig. 5. If the cost of fuel rises, the line GH would be higher and have a steeper slope. If the cost of fuel lowers the line would be lower and have a "flatter" slope. A general equation may be written which takes the cost of fuel into account. This equation must be written in such form that when the cost of fuel becomes zero the line GH will fall on and coincide with the line EF.

Examination of the graph, Fig. 5, readily discloses the fact that in order to accomplish this result, the equation must be written in such form that the line GH must "hinge" or rotate about the point of intersection of the lines GH and EF, which is shown as the point J. The equation as already written, viz:

	Constant cost		Variable operating cost	
T_c =	25,650	+	.002608	E may, therefore,

be re-written in the following form

$$T_c = 22{,}800 + (.00035 + .000645\ P)\ (E + 1{,}100{,}000) \quad \ldots\ldots (10)$$

where P = cost of coal in dollars per gross ton and

E = net kw. hrs. of electric energy produced per month. In this equation, the constant $22,800 represents the vertical height KJ. The second constant, viz: .00035 represents the **slope** of the line EF. The next quantity .000645P brings in the price of coal and is obtained by subtracting the slope of EF (.00035) from the slope of GH (.002608) and dividing the remainder by the price of coal on which the graph was based, (viz: $3.50), thus:—

.002608 — .00035 = .002258 and .002258 ÷ 3.50 = .000645, or the value of .002258 = .000645 P.

In the next expression, viz: (E + 1,100,000), the symbol E represents the net kw. hrs. produced per month and the constant (1,100,000) represents the horizontal distance OK on the graph.

The general equation, as so far developed, allows for variations in the price of coal, but requires a constant maintenance of the assumed boiler efficiency, viz: 80%. The equation can be made more general for a given installation by adding a value for boiler efficiency. A change in boiler efficiency is equivalent to a change in the price of coal in the inverse proportion. The equation can, therefore, be re-written

$$T_c = 22{,}800 + \left(.00035 + .000645\ P\ \frac{.80}{B}\right)\ (E + 1{,}100{,}000) \quad \ldots\ldots (11)$$

where P = Price of coal in dollars per gross ton;
B = Boiler efficiency expressed as a decimal
E = Net kw. hrs. produced per month.

There is one further variable which has a considerable bearing on the cost of electric energy. This is the turbine efficiency or the "Water Rate" of the turbine.

On account of the cutting of the nozzles and blades due to the continuous wear of the particles of steam passing over them and also due to sludge deposits on the blades in the latter stages of the turbine, the water rate of the turbine often increases materially with the length of time it is kept in service.

By referring to Fig. 4, it will be seen that the water rate of the turbine used as a basis of this study consists of a constant of 12,000 lbs. of steam per hour plus a variable or increment steam requirement of 10.6 lbs. per hour. In other words, an equation for the steam requirements may be written as steam requirements = 12,000 + 10.6 E where E is the energy produced in kw. hrs. per hour. With the steam conditions under which this turbine operates, the "increment steam" per "increment kw. hr."

is 10.6 lbs. which is equivalent to 13,650 Btu. in steam at the turbine throttle. A change in this water rate will be equivalent to a change in the price of fuel, so far as its effect on the cost is concerned, and the variation in cost will be in direct proportion to the variation in water rate. This factor can, therefore, be inserted in the general equation, which can then be written

$$T_c = 22{,}800 + \left(.00035 + .000645\ P \times \frac{.80}{B} \times \frac{T}{13650}\right)(E + 1{,}100{,}000) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

80% efficient boilers and $3.50 coal with the "increment" steam at turbine equivalent to 13,650 Btu. and the conditions due to long operations change to $3.50 coal—60% efficiency boilers and an increment heat in steam of 15,000 Btu.

Starting on the "cost of fuel," scale at $3.50 coal, point 1 of Fig. 6, move horizontally to the left to the 60% boiler efficiency line shown at point 2. Draw the diagonal line connecting point J with point 2 and extend this line to intersect the fuel scale line at point 3. Move horizontally to the left again until the 15,000 Btu. increment heat line is intersected as at point 4 and draw the diagonal line

GRAPHICAL REPRESENTATION OF CHANGE IN MONTHLY COST OF PRODUCING ELECTRIC ENERGY DUE TO VARIATIONS IN OPERATING EFFICIENCY OF BOILERS OR TURBINES.

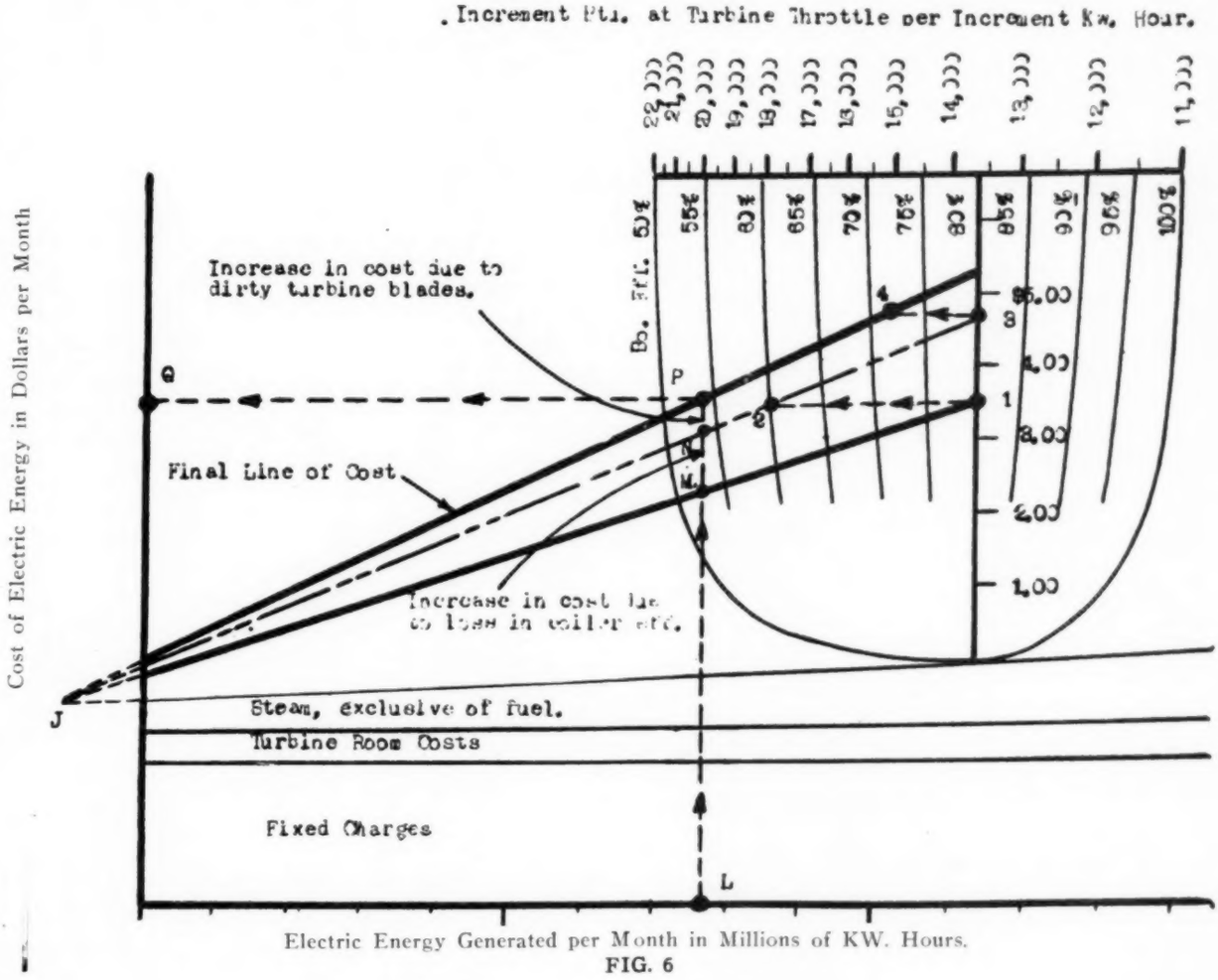

Increment Btu. at Turbine Throttle per Increment Kw. Hour.
Cost of Electric Energy in Dollars per Month
Increase in cost due to dirty turbine blades.
Final Line of Cost
Steam, exclusive of fuel.
Turbine Room Costs
Fixed Charges
Q
P
J
L
Electric Energy Generated per Month in Millions of KW. Hours.

FIG. 6

where T_c = total cost of electric energy in dollars per month

P = price of coal in dollars per gross ton

B = Boiler efficiency expressed as a decimal.

T = Increment heat at the turbine throttle in Btu. per increment kw. hr.

E = Energy produced in kw. hrs. per month.

The graphic charts may be used to show the change in monthly cost due to changes in operating efficiency of the boilers or turbines. For example: Suppose a generating station has been operating with

connecting points 4 and J. This line will be the final cost line.

If the load L is carried, the monthly cost will be shown at Q. The original operating cost would be shown by the vertical height LM and the increased operating cost would be shown by the vertical distance MP. This increase in operating cost would be made up of two items, viz: an increase in cost due to loss in boiler efficiency MN and a further increase in cost due to loss of turbine efficiency NP.

In the actual operation of any generating unit, there will be a change in the efficiency of both boilers and turbines with changes in the load. A given boiler plant may be designed to give its maximum thermal efficiency at 200% of rating. If the boilers are loaded to a greater production than this, the added load must be carried at some sacrifice in efficiency. If the boiler plant is greatly overloaded, there will be a big loss in efficiency. The curve on Fig. 7 shows a typical "efficiency-load" curve for a modern steel works boiler installation.

Typical Efficiency Curve of Steam Boilers Operating at High Ratings.

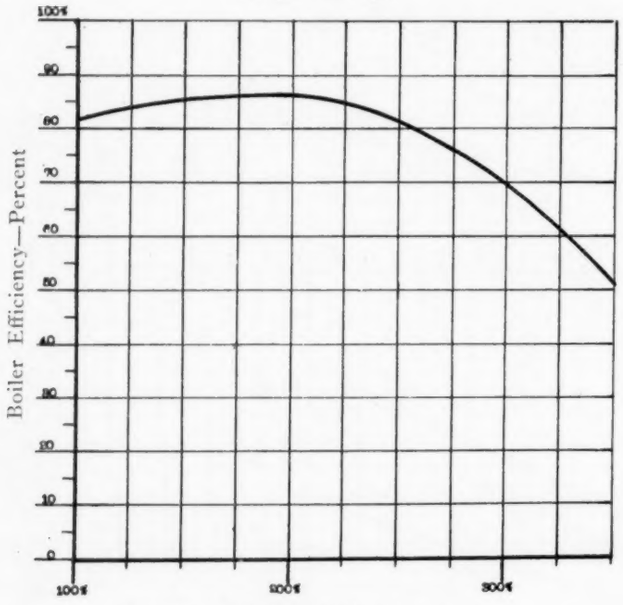


FIG. 7.

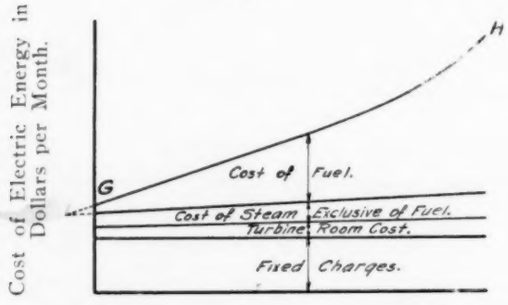

Cost of Electric Energy in Dollars per Month.
H
G
Cost of Fuel.
Cost of Steam Turbine Room Cost. Exclusive of Fuel.
Fixed Charges.
Electric Energy Produced in Kw. Hrs. per Month.

FIG. 8.

The load on a steam turbine is controlled by throttling the steam and by the number of nozzles through which steam is being admitted. If the turbine is loaded much beyond its point of maximum thermal efficiency, there will be a noticeable drop in the efficiency. This drop in efficiency of both units at high loads will result in a rise in costs and cause the line of total cost to bend upward as shown in Fig. 8. These curved lines are developed in the graphic charts.

It is interesting to see what effect on the cost, different types of equipment will have. For example, equipment manufacturers often develop their product to a very high state of thermal efficiency and designing engineers are often tempted to use the high efficiency developments.

High thermal efficiency tends to lower the line GH of Fig. 8 and to flatten its slope, but care must be used to avoid raising the investment charges so that the condition shown in Fig. 9 does not result, as the aim of all industry is to produce a unit of product at the minimum cost. In this Figure, the fixed charges and original producing costs are shown in full lines. The new conditions are shown in dotted lines. The greater thermal efficiency of the second proposal has flattened the slope of the cost line, but the increased investment charges have raised the constant costs. At a certain load, or production L, the cost in either case would be the same, but the company would be better off in the first case than in the second case, because of a

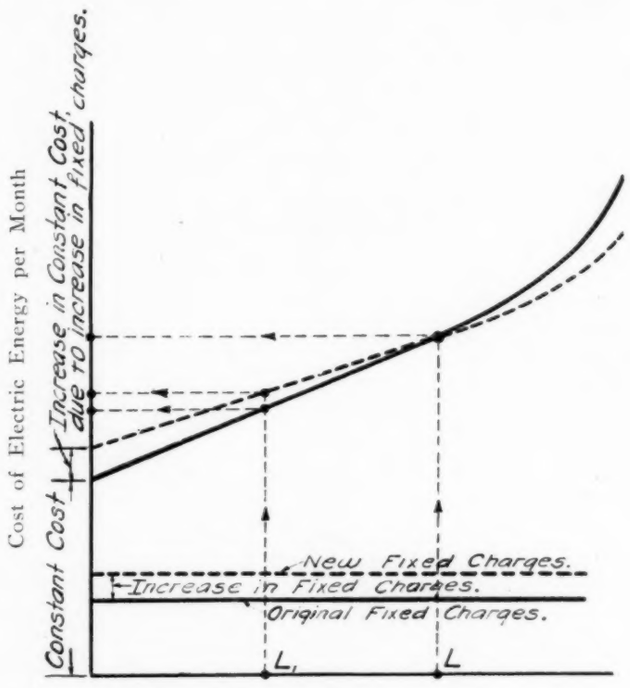

Cost of Electric Energy per Month
Increase in Constant Cost, due to increase in Fixed charges.
Constant Cost
New Fixed Charges.
Increase in Fixed Charges.
Original Fixed Charges.
L1
L
Electric Energy Generated in Kw. Hours per Month.

FIG. 9.

smaller investment in the station. If the average load on the unit is smaller than L, as shown by L_1, the company actually loses money by installing the unit of greater thermal efficiency as indicated by the vertical height between the upper lines. The high efficiency unit would not be justified until the average load was greater than L. This point is nicely illustrated in both of the large charts published with this paper. Take for example the Chart of Electric Costs and note that the point of maximum thermal efficiency is reached when the generator is working at about 72% of rating. The point of minimum operating cost is not reached until the generator is working at 91% of rating and the point of minimum total cost is not reached until the generator is operating at 109% of rating. The boilers are then being driven at a rate which has

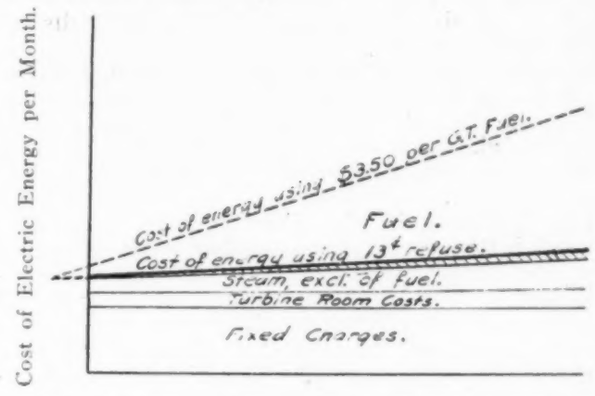
caused them to drop off in efficiency from their designed point of 86% at 200% load to 73% at about 273% load.

The average isolated steel works operates its generating equipment at a point where the average load is 50% of rating, or slightly less than that. The knowledge that this equipment must operate at 109% of rating in order to reach the point of minimum cost seems to suggest that the investments in generating stations are badly out of line with their operating characteristics, if we attempt to produce "a unit of product at a minimum cost."

Another place where errors in estimated savings often arise is in the case of reduced energy consumption due to changes in equipment. For example, energy costs 6 mills per kw. hr. and changing some power consuming unit will save a million kw. hrs. per month. This looks like a saving of .006 × 1,000,000 = $6,000.00 a month, but is it? The probabilities are it is not. Examination of the chart shows that dropping a part of the load on a generator will not effect the "constant" portion of the costs. The "increment" cost of energy is the only part effected. This increment cost may be 2.5 mills per kw. hr., so that the actual savings will be .0025 × 1,000,000 = $2,500.00 a month, which is a considerable shrinkage when $6,000.00 was expected. I have had some interesting applications of this chart, which show the effect of changes in operating conditions on the cost of electric energy.

On one occasion, I was sent to investigate a coal mine which operated its power house on belt pickings and other mine refuse. This refuse averaged 11,000 Btu. per pound and cost 13 cents a ton delivered to the bunkers.

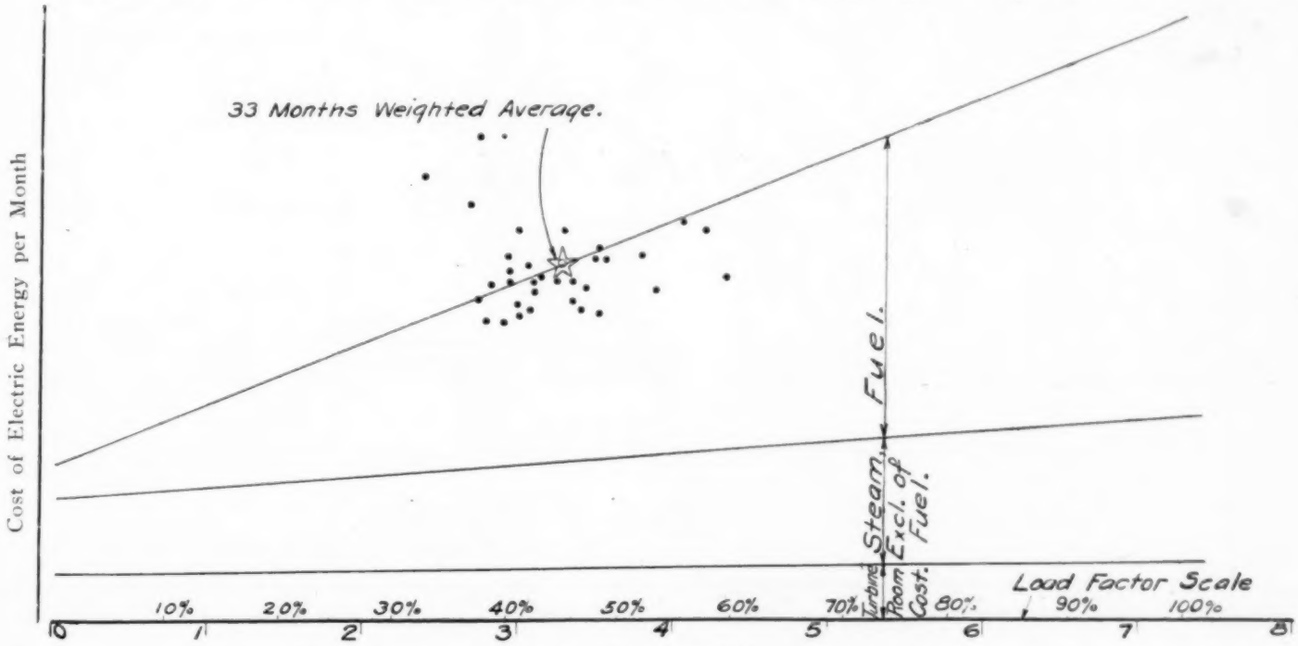
Figure 10 shows the resulting effects on the cost. The dotted line at the top of the figure indicates the cost of energy when $3.50 fuel is used and the upper full line, the cost of the same quantity of energy when 13 cent fuel is used. The vertical height of the shaded portion of the figure indicates the item of fuel cost, in the cost of power for this mine. An increase or decrease in power requirements at this mine has very little effect on their cost of power as most of their cost is constant regardless of the quantity of energy produced. This also indicates the radical effect on the cost of power which results from the "book value," which is placed on blast furnace gas and by-product heat in steel works accounting.


Cost of Electric Energy per Month.
Cost of energy using $3.50 per G.T. Fuel.
Fuel.
Cost of energy using 13¢ refuse.
Steam, excl. of fuel.
Turbine Room Costs.
Fixed Charges.

Electric Energy Generated in Kw. Hours per Month.

FIG. 10.

This method of analysis of electric costs was applied to an actual turbine in a works where the electric station was completely isolated from the rest of the power plant, so that the total costs shown on the cost sheet applied exclusively to the cost of electric energy and there was no necessity of any sub-division of steam costs among departments. The coal costs were corrected to a uniform value in order to get a proper relative comparison. The results are shown on Fig. 11, and are somewhat erratic. This is easily explained by the fact that all costs



Net Energy Generated in Millions of Kw. Hours per Month.

FIG. 11.

occurring in any month, no matter what the cause, were charged into that particular month. As a result, the three high points at the left, represent months of low production due to major repairs. During parts of two of these months, the turbine was re-bladed. The low points at the right represent months when this unit was in good shape and was carrying extra load due to emergencies that arose in other interconnected power stations. The star shows the weighted average production and cost for 33 successive months of operation and falls almost exactly on the line.

Several steel companies are at present engaged in analyzing their steam and electric costs on this basis. In Fig. 12, the results of the first of these is presented. This shows the operating costs for a boiler plant over 24 successive months of the years 1926 and 1927.

As indicated in the diagram, the costs were divided into Repairs, Direct Labor, Coal Handling and Fuel. Each item in each subdivision was carefully analyzed and plotted over the two year period to determine the percentage of constant and variable costs. The total for each sub-division was then assembled and the constant and variable costs determined. Major repairs which recurred at comparatively long but regular intervals of time were funded, so that each month carried its proper share of these major items and the total was not loaded onto any particular month. Monthly fuel costs were then corrected to the weighted average price of fuel and the whole put together in the diagram of Fig. 12. Note that the range of average monthly load over the 24 months varied from 7,000 to 13,000 boiler horse power, while the maximum cost variation over this range of load was 2% plus or minus.

In closing, I wish to call attention to one very important fact. The two graphic charts are general and cannot be expected to yield accurate results for a given plant regardless of its size or the local conditions surrounding its construction and operation. This statement applies with equal force to the percentage variation between the constant and variable costs shown on Table No. 1 and No. 2.

The local conditions surrounding a given installation are in many cases the most important single element entering into the cost of operation and the "percentage split" between constant and variable costs will be governed almost entirely by them. Charts of this type can be easily set up for any given plant or unit and the changes in cost due to a change in operating conditions can then be forecast with the assurance that the actual results will agree reasonably with those that were expected.

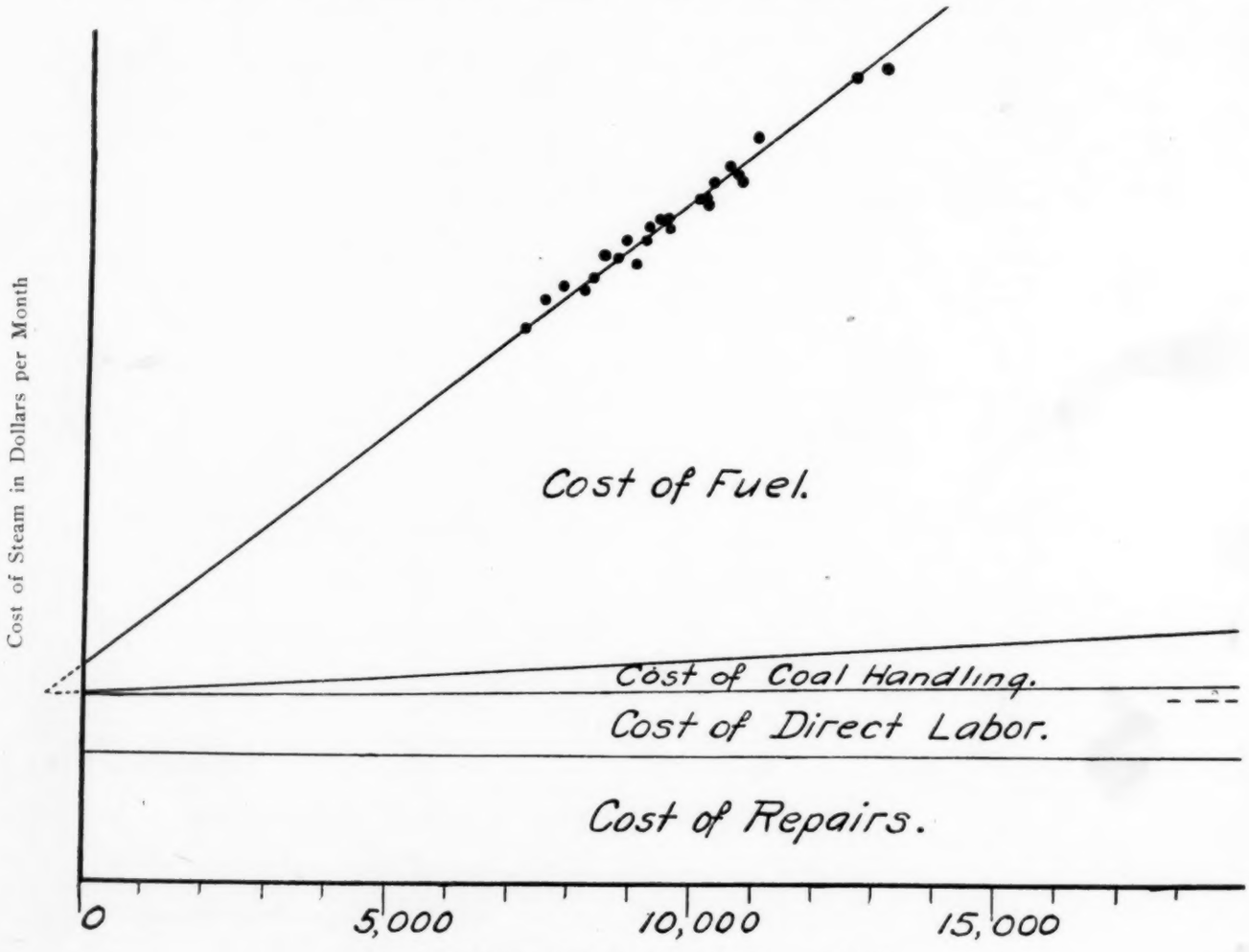
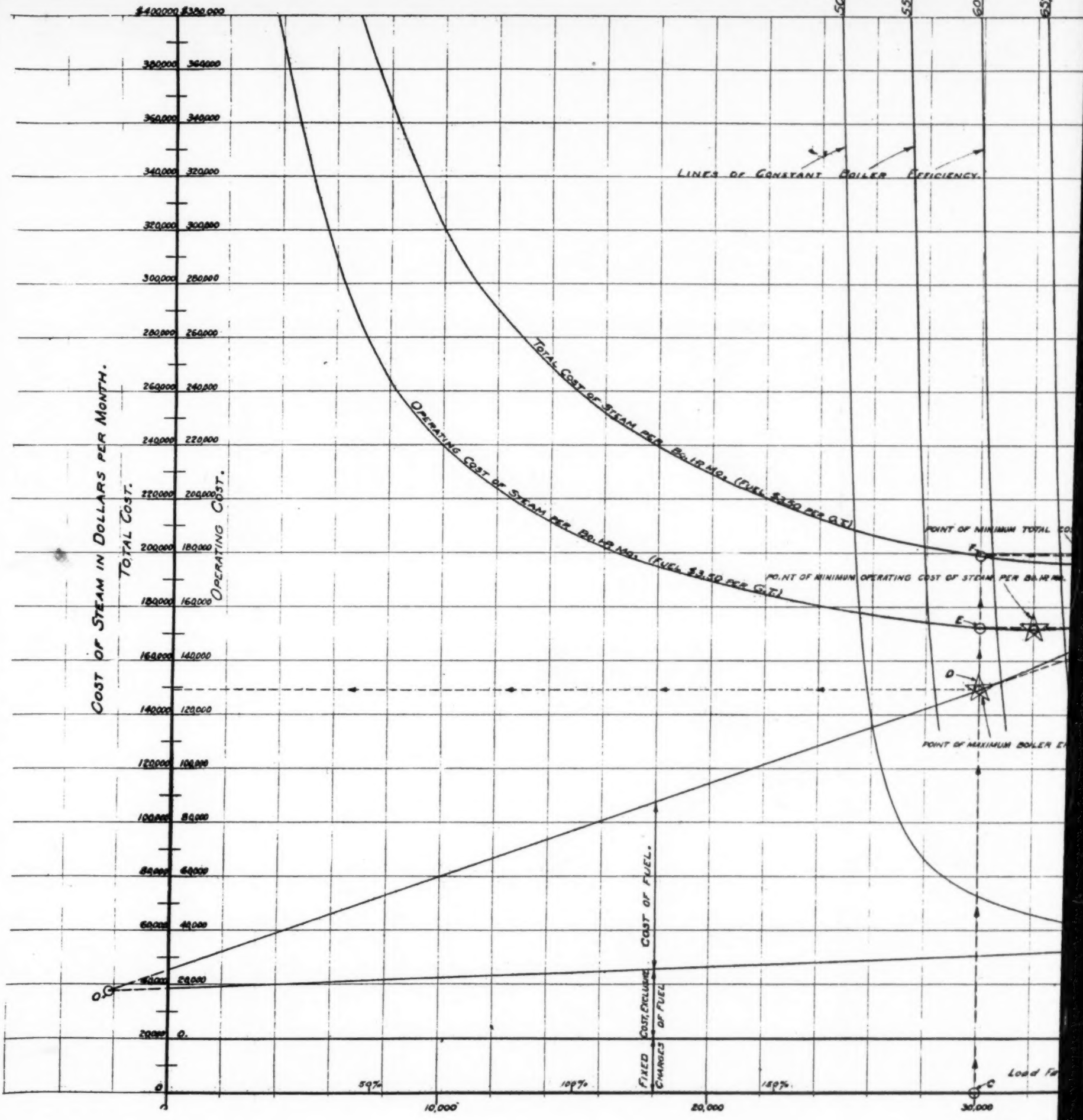
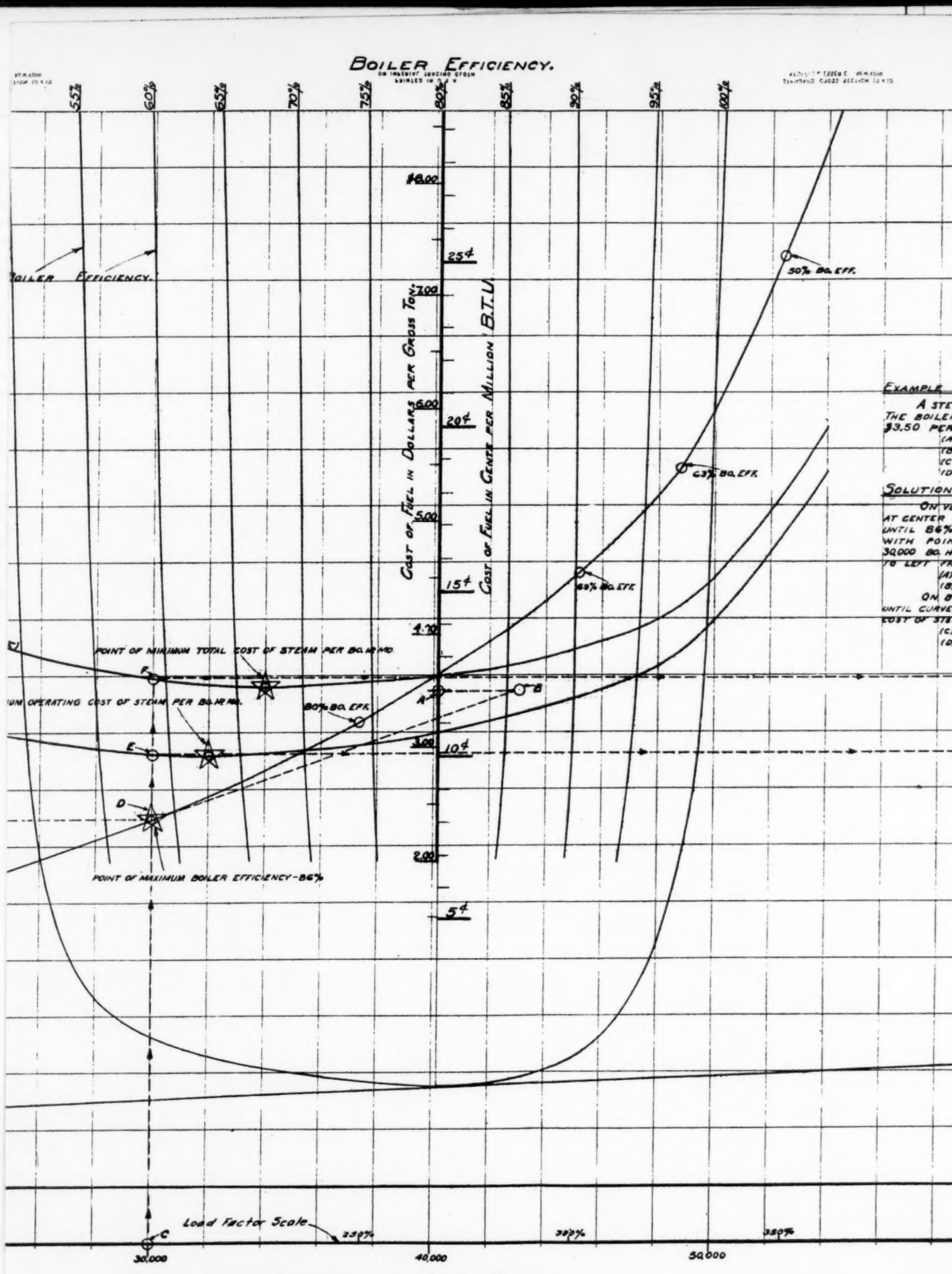
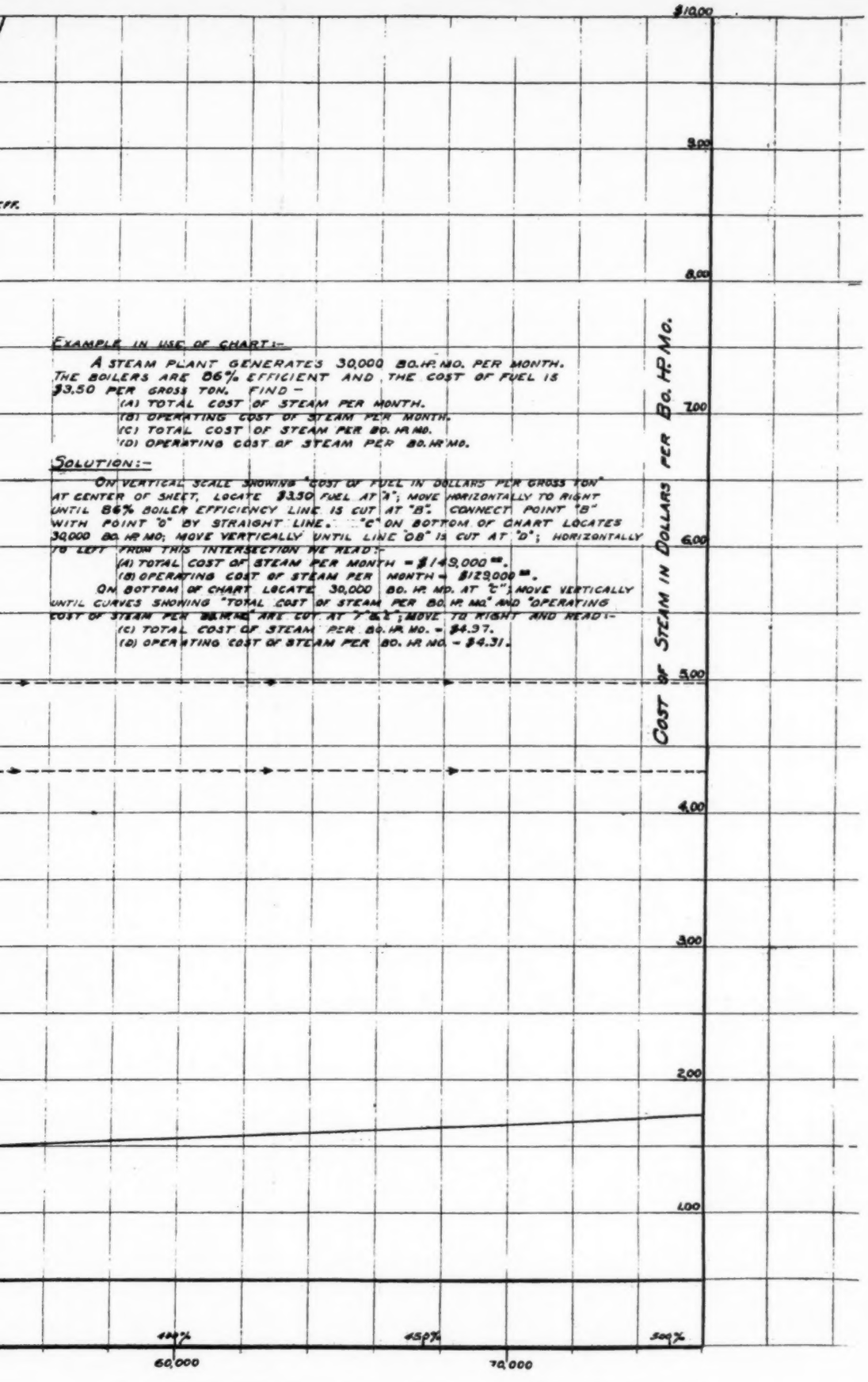


FIG. 12.


$400000 $300,000
380000 360000
360000 340000
340000 320000
320000 300000
300000 280000
280000 260000
260000 240000
240000 220000
220000 200000
200000 180000
180000 160000
160000 140000
140000 120000
120000 100000
100000 80000
80000 60000
60000 40000
40000 20000
20000 0.
0
50%
55%
60%
65%
LINES OF CONSTANT BOILER EFFICIENCY.
TOTAL COST OF STEAM PER BO.HR MO. (FUEL $3.50 PER G.T.)
OPERATING COST OF STEAM PER BO.HR MO. (FUEL $3.50 PER G.T.)
POINT OF MINIMUM TOTAL CO
POINT OF MINIMUM OPERATING COST OF STEAM PER BO.HR MO.
POINT OF MAXIMUM BOILER E
TOTAL COST.
OPERATING COST.
COST OF STEAM IN DOLLARS PER MONTH.
FIXED COST, EXCLUDING COST OF FUEL.
CHARGES OF FUEL
5%
10%
15%
10,000
20,000
30,000
BOILER HORS


BOILER EFFICIENCY.
55%
60%
65%
70%
75%
80%
85%
90%
95%
100%
$8.00
7.00
6.00
5.00
4.00
3.00
2.00
25¢
20¢
15¢
10¢
5¢
COST OF FUEL IN DOLLARS PER GROSS TON
COST OF FUEL IN CENTS PER MILLION B.T.U.
BOILER EFFICIENCY.
50% BO. EFF.
63% BO. EFF.
69% BO. EFF.
80% BO. EFF.
POINT OF MINIMUM TOTAL COST OF STEAM PER BO. H.P. MO.
UM OPERATING COST OF STEAM PER BO. H.P. MO.
POINT OF MAXIMUM BOILER EFFICIENCY-86%
A
B
C
D
E
F
Load Factor Scale
33⅓%
30,000
40,000
50,000
EXAMPLE
SOLUTION
BOILER HORSEPOWER MONTHS PER MONTH GENERATED.



EXAMPLE IN USE OF CHART:-

A STEAM PLANT GENERATES 30,000 BO. HP. NO. PER MONTH. THE BOILERS ARE 86% EFFICIENT AND THE COST OF FUEL IS $3.50 PER GROSS TON. FIND -

(A) TOTAL COST OF STEAM PER MONTH.
(B) OPERATING COST OF STEAM PER MONTH.
(C) TOTAL COST OF STEAM PER BO. HR MO.
(D) OPERATING COST OF STEAM PER BO. HR MO.

SOLUTION:-

ON VERTICAL SCALE SHOWING "COST OF FUEL IN DOLLARS PER GROSS TON" AT CENTER OF SHEET, LOCATE $3.50 FUEL AT "A"; MOVE HORIZONTALLY TO RIGHT UNTIL 86% BOILER EFFICIENCY LINE IS CUT AT "B". CONNECT POINT "B" WITH POINT "O" BY STRAIGHT LINE. "C" ON BOTTOM OF CHART LOCATES 30,000 BO. HP MO; MOVE VERTICALLY UNTIL LINE "OB" IS CUT AT "D"; HORIZONTALLY TO LEFT FROM THIS INTERSECTION WE READ:-

(A) TOTAL COST OF STEAM PER MONTH = $149,000 ans.
(B) OPERATING COST OF STEAM PER MONTH = $129,000 ans.

ON BOTTOM OF CHART LOCATE 30,000 BO. HR MO. AT "C"; MOVE VERTICALLY UNTIL CURVES SHOWING "TOTAL COST OF STEAM PER BO. HR MO." AND "OPERATING COST OF STEAM PER BO. HR MO." ARE CUT AT "F" & "E"; MOVE TO RIGHT AND READ:-

(C) TOTAL COST OF STEAM PER BO. HR MO. = $4.97.
(D) OPERATING COST OF STEAM PER BO. HR MO. = $4.31.

COST OF PRODUCING STEAM IN A BOILER HOUSE OF 15,000 BO. HR INSTALLED CAPACITY (BLAST FURNACE GAS-FIRED BOILERS.)

WBS-CM

Incre

Example in use of Chart:-

A 15,000 Kw. Turbo-generating station is supplied with steam from 66% efficient boilers burning fuel at $3.30 per gross ton. The monthly electric energy output of the station is 7,872,000 Kw. hours. Find:-

(A) Total cost of electric energy in Dollars per month.
(B) Operating cost of electric energy in Dollars per month.
(C) Total cost per Kw. hour.
(D) Operating cost per Kw. hour.

Solution:-

On vertical scale showing "Cost of Fuel in Dollars per G.T." locate $3.30 fuel at "A"; move horizontally to right until 66% boiler efficiency line is cut at "B". Connect "B" and "O" by straight line. At bottom of chart, locate 7,872,000 Kw. hrs. per month at "C"; move vertically until line "OB" is intersected at "D"; to the left read:-

(A) Total cost of electric energy in Dollars per month = $45,000.
(B) Operating cost of electric energy in Dollars per month.

From "C" at bottom of chart move vertically until curves showing "Total cost per Kw. hour" and "Operating cost per Kw. hour" are intersected at "E" and "F"; horizontally to right we read:-

(C) Total cost per Kw. hour = 0.362¢
(D) Operating cost per Kw. hour = 0.372¢

Lines of Constant Boiler Efficiency

Lines of Constant Heat Consumption of Turbine

Point of max. eff.

Total cost per Kw. hr. (Fuel $3.30 per G.T.) F

Operating Cost per Kw. hr. (Fuel $3.30 per G.T.)

Cost of Electric Energy in Dollars per Month.

Total Cost.

Operating Cost.

Fixed Charges.

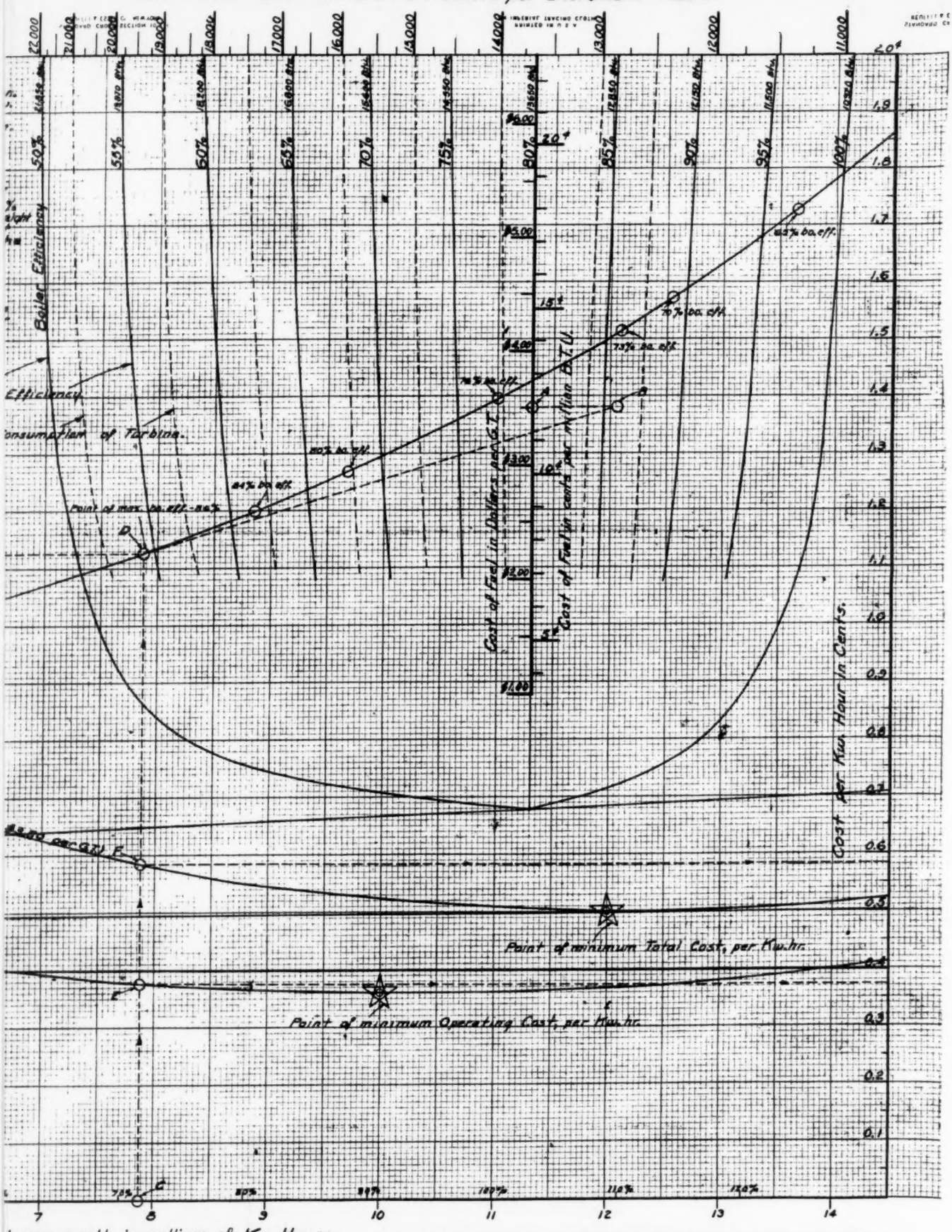
Steam Turbine excl. of Fuel Cost.

Fuel Cost.

Boiler Efficiency

Load Factor Scale

Electric Energy generated per month in m


Increment Btu. at Turbine Throttle per Increment Kw.hr.
Boiler Efficiency
Efficiency
Consumption of Turbine.
Cost of Fuel in Dollars per Hour
Cost of Fuel in cents per Million B.T.U.
Cost per Kw. Hour in Cents.
Point of max. Op. eff. - 84%
Point of minimum Total Cost, per Kw.hr.
Point of minimum Operating Cost, per Kw.hr.
per month in millions of Kw. Hours.

COST OF PRODUCING ELECTRIC ENERGY
BY HYPOTHETICAL 15,000 KW. TURBO-GENERATOR.
(BLAST FURNACE GAS-FIRED BOILERS.)

WBS-CM

*Report of Committee on Electric Heat**

By GEORGE H. SCHAEFFER, CHAIRMAN†

THE object of the annual report of the committee on electric heat is to acquaint the membership with the most recent developments and applications in this particular field. The previous reports have covered the subject from the initial electric heat experiments and traced the developments to the present time. This report therefore aims to feature only the activities which have developed since the last convention of our association.

In accordance with request, the committee has included the subject of welding—covering the developments, as relating to Steel Mill Work, and with the idea of bringing the whole subject up to date.

TREND OF POWER COST

The comparison of cost of electric power does not compare favorably with the cost of fuel on a B.T.U. basis, nevertheless this is not necessary because it is the ultimate or final cost of the unit cost. The inherent advantages of electric heat more than offset the difference in cost when compared on a B.T.U. basis.

Public utilities furnishing electrical energy have undergone drastic changes since the World War or about the year 1920. These changes have been in the nature of large consolidations resulting in the tying together of several small properties, the energy being generated by base load plants of large capacity as well as the interchange of energy between the larger public utilities whose load characteristics are different.

The grouping together of a number of properties has brought about savings which have reflected themselves in the rate schedules of public utilities companies. Where formerly each property established its own executive and engineering offices, there now is only one office controlling the policy and engineering of the total group.

The consolidations have also enabled the public utilities companies to employ the service of highly trained specialists. These specialists have obtained economies heretofore thought impossible in the generation and transmission of electrical energy.

In order to show more vividly the results of the above mentioned economies, we have incorporated the curve Fig. 1, which shows the per cent change in average rates, using the year 1920 as a basis. The curve shows conclusively the trend.

The total number of operating companies has decreased from approximately 6,800 in 1920 to 4,450 at the beginning of 1928, which shows the large trend of consolidations, wiping out the small plant and putting in larger generating equipment to take care of the requirements, and before this year is over there will be a still larger decrease in the number of operating companies.

During this period the total number of kilowatt hours of current used has increased from approximately 26,000,000,000 to 58,000,000,000 at the beginning of 1928, which shows also that the largest trend has been for power on large users. In other words, they show three curves—domestic, commercial and power.

The power curve increased from approximately 17,000,000,000 kilowatt hours in 1920 to 42,000,000,000 kilowatt hours at the beginning of 1928. This tremendous increase naturally is forcing the cost of power down in addition to the fact that the small central stations are being consolidated and there is a lot thrown over on large stations who have up to date equipment, making possible for them to generate power at a lower cost and also sell it at a better price to the user.

During this same period the total change in generating capacity has increased from 15,000,000 KVA to 29,600,000 KVA at the beginning of 1928, with an estimated generated capacity of 31,000,000 KVA at the end of 1929. So with this figure you

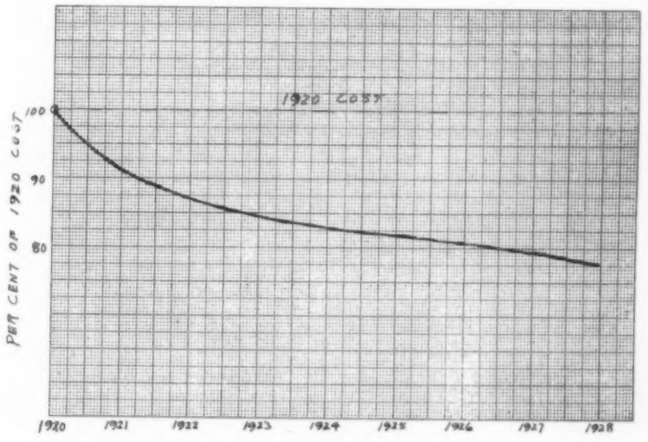


FIG. 1

can readily see that the trend has to be downward and that the power companies have to make rates lower in order to get users to use up this tremendous amount of energy which is being provided.

In studying the new tariffs, one is impressed with clauses pertaining to contract capacities, power factor, delivery voltage, coal prices—annual and monthly billing of which materially affect the consumers billing.

Those consumers who have made a study of their load and power factor and adjusted same find that they are able to decrease the cost of their electrical energy. Those who have not made any adjustments are finding it somewhat difficult to affect a saving under the new tariffs.

*To be presented before A. I. & S. E. E. Annual Convention, June 25-28, 1928.

†Elec. Engr., The Carpenter Steel Co.

Committee
E. N. Calhoun, Edwin L. Wiegand Co.
George H. Chutter, General Electric Co.
C. F. Cone, George J. Hagan Co.
R. M. Cherry, General Electric Co.
J. D. Donovan, Central Alloy Steel Corporation.
George P. Mills, Wm. Swindell & Bros. Co.
F. C. Watson, International Nickel Co.
J. C. Woodson, Westinghouse Electric & Mfg. Co.

I believe that there is a general tendency for the Public Utility Company to offer rate tariffs that will give the consumer a rate equal to that for which the consumer can make his own power.

No doubt, in many districts special tariffs are offered to those consumers who have a large electric heating or melting load that can be supplied during the Utility Company's low peak hours.

Some of the tariffs are rather hard to analyze especially for the man who has not made some study of the technical terms, such as power factor, contract capacities in KVA or KW, load factor, power demand, etc. In a good many cases the choice of tariff applicable to a plant is left to the recommendation of the Utility Sales Engineer. Of course this is true only where the management does not understand the contract and does not care to call in outside assistance.

To get the advantages of the lowest rates offered by the Public Utilities the consumer must study his load factor, the capacity demand and operating conditions, with the idea of reducing the demand, improving the power factor and building up the load factor.

INDUSTRIAL HEATING

Under this heading we class all resistance type furnaces, dividing them into:

High Temperature—above 1850° F.
Medium Temperature—1200 to 1850° F.
Low Temperature—below 1200° F.

Industrial heating is practically a new field for public utilities companies. They realize the advantages of an industrial heating load with its high load factor and exceedingly good power factor and are beginning to favor this class of business with rates such as a load of this character should earn. It is doubtful whether these rates will ever reach an equal basis from B.T.U. cost compared with other fuels.

This, however, is certainly not necessary as with electric heat the B.T.U. cost is not a significant factor to the manufacturer when labor saving, accurate temperature control, low maintenance cost and better working conditions are considered. Present day business of necessity is done on a large scale with large production programs. Industrial electric heat fits ideally into this production program which is impossible with other forms of fuel.

ELECTRIC ANNEALING FURNACES

Interest in the electric annealing of high grade alloy and tool steels during the past year is indicated by the installation of a number of units in new plants, also by the addition of extra furnaces in plants already using electric annealing equipment.

OPERATING DATA

Production has an important bearing on the power consumption. Due to the more specialized industry in which those furnaces are being used, accurate operating costs are difficult to obtain. Each proposition must be worked out, taking into consideration the particular conditions to be met.

On bar annealing furnaces the condition of the bars as to straightness materially affects the quantity which may be loaded in a given furnace. In some plants running heavy loads of standardized straight material power consumption is as low as 250 KWH per ton on a 42 hour annealing cycle. On other plants running similiar material, except that the bars are not straightened, resulting in light loads, the power consumption runs as high as 550 KWH per ton.

It is pointed out that the cost of fuel fired annealing under the different conditions would be proportional. It can be stated that every installation coming to the committee's attention is satisfactory to the user from cost of operation standpoint.

The following examples are taken from furnaces in daily use:

APPLICATION NO. 1

Product—Bearings.

Work done—Carborizing. Non-uniform rollers and cages.

Equipment—Make—GE Co. Box type.
Date installed—1925-26.
Average load—47393 lbs. gross—18,297 net.
Maximum load—
Size—64" wide, 68" long, 1 section.
Number of installations—1.

Temperature—1700 deg. F.

Time per cycle to come to desired temperature—1100 to 1740 deg.—4 hours.
Held this temperature for 18 to 27 hours.

Hours operated per day)
Days operated per month) Continuous

Electrical load—27,000 KWH/month.
Pounds per KWH—5.75 lbs. gross—2.22 lbs. net.
Maximum demand—110 KW.

Remarks—Cost of operation not easily compared with fuel oil furnaces.
Quality better in electric furnace.

APPLICATION NO. 2

Product—Alloy Steel Stock.

Work done—Annealing bars, tubes and heavy wire. Uniform size.

Equipment—Make — Electric Furnace Company, Salem, Ohio.
Pit type.
Installed—May, 1927.
Average load—30 tons.
Maximum load—85 tons.
Size—9'0" wide, 21'6" long, 6'6" high.
One section.
Number of installations—2.
Ventilation—Circulating cooling system.

Temperature control—Instrument—Double control top and bottom.

Time per cycle to come to desired temperature—16 hrs. to 1450 deg. F.—held this tempt. for 30 hrs.

Hours operated per day—Continuous.

Electrical load—100,000 KWH/month.
KWH per ton 355 KWH for tube stock.
Maximum demand 900 KW—Average 750 to 800.

Installed to obtain uniform results.

Opinion of installation from users standpoint—
Very satisfactory—have second furnace—installed January, 1928.

APPLICATION NO. 3

Product—Alloy Steel Stock.
Work done—Heat treating.
Size—Non-uniform.
Equipment—Make—Wm. Swindell & Brothers—Box type.
Date installed—January, 1927.
Average load) varies—150 KW.
Maximum load)
Size—8'0" wide, 9'0" long, 18" high—1 section.
Number of installations—1.
Temperature control—Instrument—Temperature—1400 to 1600° F.
Time—Per cycle—Varies to come to desired temperature—Cooling 1450 to 920 required 32½ hours.
Cost of operation—Average cost of KWH—Radiation losses 25 KW/hr. at 1500 deg. F.
Why installed—For special work.
Opinion of installation from users standpoint—Doing very satisfactory work.
Idle cost per hr.—17.3c at $.008 per KWH—Temperature—1450 deg. F.

APPLICATION NO. 4

Product—Alloy Steel Stock.
Work done—Annealing of bar stock.
Size of bars—Up to 4" square—Various lengths 8' to 20'0".
Equipment—Make—GE Co.
Date installed—1926.
Average load—10 tons.
Maximum load—20 tons.
Size—54" wide, 30' long, 36" high.
Number of installations—1.
Temperature control—Instrument—Double control—One at each end.
Temperature—1500 deg.
Time to come to desired temperature—2 to 9 hrs. Held at 1500 deg., 17 to 25 hrs.
Hours opearted per day) Continuous.
Days operated per month)
Electrical load—67,500 KWH/month.
KWH per ton—445 KWH/ton at 1500.
285 KWH/ton at 1250.
Maximum demand—510 KW.
Why installed—One of first installations—To see what quality would mean.
Opinion of installation from users standpoint—Very good, but not the right size for most economical production.

APPLICATION NO. 5

Product—Bearings.
Work done—Annealing. Size of work non-uniform.
Equipment—Make—Wm. Swindell & Bros.
Date installed—1926.
Average load—12 tons.
Maximum load—20 tons.
Size—6' wide, 18" long, 2½' high, 1 section.
Number of installations—1.
Temperature—1650 deg.
Time per cycle to come to desired temperature—14 to 16 hours to 1650 deg.
Hours operated each day) Continuous.
Days operated each month)
Electrical load—106,800 KWH per month.
KWH per ton 325 KWH/ton at 1650 deg. on bar stock—6 to 10 hrs. run.
KWH per ton 225 KWH/ton at 1250 deg. on bar stock—9 to 9½ hrs. run.
Maximum demand—325 KW.
Cost as compared with previous heating method—Competing with 50c natural gas.
Why installed—Uniform annealing.
Opinion of installation from users standpoint—Very good.
27 hours Soaking period 1500 deg. F.—630 KWH per ton.

USES OTHER THAN ANNEALING 1850 DEG. F. AND ABOVE

Forging and High Speed Steel Hardening

The Globar type of heating unit has for some time looked very attractive for the high temperature. Improvement has been made in the element and in the terminal connections in the past year or two and a satisfactory furnace using these elements now seems a possibility. Several Globar furnaces have been built in the past ten years but as a general rule these furnaces have not been entirely successful, due to short life element and difficulty of making proper contact with the element. Experiments are being continued.

COPPER BRAZING

The process of copper brazing in a neutral or reducing atmosphere has been used for one manufacturer for the past four or five years. This company now has installed a total of ten such furnaces electrically heated having a total connected load of about 3000 KW. The furnaces are of the ribbon resistor type and operate at 2000 to 2100 deg. F.

The parts to be brazed are heated to the proper temperature and cooled with the furnace or under a cooling hood until they have reached a temperature below the point when they will oxidize.

A single chamber, two chambers, one heating and one cooling, giving an intermittently operated furnace, or a continuous type of furnace is used depending upon the parts to be brazed and the production.

A two chamber or intermittent type is shown on Fig. 2 and a continuous type on Fig. 3.

These furnaces now installed are used principally for brazing turbine and refrigerator parts. The process not only produces a very good joint between metals but also simplifies fabrication.

This process no doubt can be applied to the joining of a high grade of steel to a low grade as in the manufacture of knives, saws, axes, etc., and used for fabrication of various parts.

1200 TO 1850 DEG. F. VITREOUS ENAMELING

For the past few years there has been a great deal of interest in continuous enameling furnaces. Most of the first furnaces installed were of the combination oil-electric type. There has recently been designed an all electric continuous compensating furnace of the U-shape. The heating chamber is elevated above the floor and the drying and pre-

heating chamber is on an incline. This type of furnace also has the advantage of having the charging and discharging at the same end. A furnace of this type is now being installed.

A Box Type Vitreous Enameling furnaces has worked out very satisfactorily for enameling refrigerator linings. A double fork is mounted on one frame, both forks being operated together. A charge is taken from dryer at the same time that charge is removed from furnace, and the charge taken from the dryer is placed in furnace at same time hot charge is placed on conveyor, which returns parts

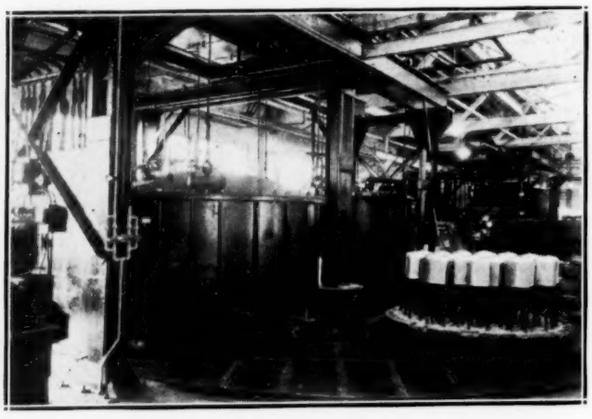


FIG. 2

to spray room. This layout has given an economy of approximately 11 pounds of enameled ware per KWH.

SHEET STEEL ANNEALING

No doubt the bright annealing of sheet steel is one of the most important subjects for the steel manufacturer, also holds out a promising field for the furnace manufacturer. While a continuous type of furnace is desirable, no doubt, there are a great many applications where the Elevator Type furnace Fig. 4 operated with inert or reducing atmosphere could be used with very satisfactory results.

The elevator furnace is now extensively used in the annealing of sheet steel and punchings as used in electrical apparatus. Some of these annealing furnaces are used with an inert or reducing atmosphere. One large electrical manufacturer has installed a total of 27 electrically heated elevator type furnaces for annealing sheets and punchings. Similar furnaces are used for annealing pressed steel parts, and blanks cut from plate by cutting torches.

The furnaces vary in size from one ton to twelve ton charge and the electrical rating is from 40 KW to 240 KW. The total connected load of the 27 furnaces is approximately 3000 KW.

The use of the electric furnace has made it possible to eliminate the heavy packing boxes which are required in the fuel fired furnace. The weight of the packing boxes was about the same as the net weight of the charge, also the labor of packing the boxes was much greater than loading on an open car.

The quality of the product is greatly improved and the annealing cost on fuel basis only is lower with the electric furnace.

The following is a record of cost of annealing:

Type of Furnace	Energy Consumption per 100 lbs.	Cost per 100 lbs.
Oil	3.68 gallons	22 cents
Electric	10.8 KWH	13½ cents

In addition to the savings in fuel, there is a large saving in the elimination of boxes and also a large saving in floor space.

Some of these furnaces are shown on Fig. 4.

HARDENING AND DRAWING

There has been in operation for the past two years an electric car bottom furnace for hardening and drawing forgings. Fig. 5. The heating units are mounted in the car and in the roof. The car units are protected by cast alloy plates. Since it is desired to quench one piece at a time a quick raising door and quick operating car is required. The car is driven through a rack mounted on the truck by means of a motor driven pinion.

The door is motor operated with limit switches to limit travel of door also limit switches are provided to limit travel of car.

The size of furnace as shown in photograph is 6 ft. wide x 16 ft. long x 3 ft. high working dimensions, rated 240 KW.

Tests on this electric furnace and an oil fired furnace of practically the same dimensions, both used for the same type of work, operating at 1550 deg. F. hardening temperature and 900 to 1000°F drawing temperature are tabulated below. The figures on pounds of work treated include both hardening and drawing treatments.

	Electric	Oil Fired
Lbs. Treated	309130	209507
Fuel	114700 KWH	15184 Gals. oil
Cost of fuel	1¼c per KWH	6¼c per gal. in storage tank
Cost per 100 lbs.	$0.46	$0.45

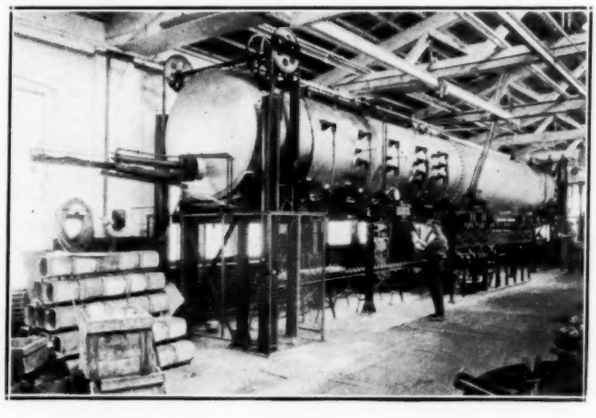


FIG. 3

In a gear treating shop using various box type oil and electric furnaces a six months' production and cost record was obtained. The oil and electric furnaces were of practically the same size and were used in the treatment of similar parts and at same temperature, operating nine hours per day.

Type of Furnace	Production	Cost per Ton
Oil	1046 Tons	$6.79 (6c per gallon)
Electric	1056 Tons	4.84 (1¼c per KWH)

LEAD HARDENING POTS

There are used today a great many lead pots for hardening steel. The electrically heated pots are being installed at an increasing rate, due to less maintenance, better working conditions, automatic control and very often less fuel consumption.

A week's record on two 8" diameter lead hardening pots, one gas heated and the other electrically heated is as follows:

Type of Pot	Production	Energy Consumption	Cost
Gas	1000 lbs.	14180 cu. ft. at 80c/14	$11.34
Electric	1000 lbs.	400 KWH at 1½c	6.00

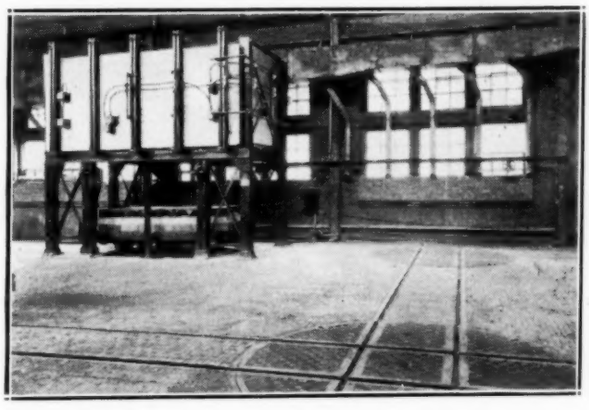


FIG. 4

CYANIDE POTS

Several sizes of electrically heated standard cyanide pots have been placed on the market in the past two years.

MISCELLANEOUS BOX TYPE FURNACE AND VERTICAL CYLINDRICAL FURNACES

There is on the market a great many standard sizes and designs of electrical furnaces for the tool room and small production.

In the case of the tool room, a furnace is used more or less intermittently, therefore, the bulk of the power required is that required to maintain furnace at temperature.

The losses from the well insulated electric furnaces is very small as compared to the losses of similar size gas or oil furnaces.

At 1½ cents per KWH for electrical heat and 80 cents per M for gas of 550 BTU, the cost of maintaining an electric furnace at a given temperature, say 1600 deg. F., is considerably less than for the gas furnace. The following table based on test gives the stand by losses of gas and electric furnaces:

Usable Dimensions Of Heating Chamber			Gas Cu Ft. To Hold at 1600°F.	Furnace Cost Per Hour at 80c per M.Cu.Ft.	Electric KWH To Hold at 1600 Deg. F.	Furnace Cost Per Hour at 1½c Per KWH
Width	Length	Height				
18"	36"	18"	190	15 cents	6	9 cents
24"	54"	20"	260	21 cents	9	13½ cents
36"	83"	23"	440	35 cents	16	24 cents

LOW TEMPERATURE, 1200 DEG. F. AND BELOW

This temperature field covers a great variety of application, such as core baking, japanning, paint drying, steel drawing, babbitt pots, solder pots, tinning pots, galvanizing, etc.

While most of these applications are not new for electric heat, it may be of interest to consider the type of equipment now available for some of the applications.

AGEING IRON CASTINGS

The ageing of large iron castings to prevent deformation in service due to cooling strains, may be done in electric furnaces. The uniform temperature distribution eliminates the possibility of hot spots which might occur with flames, and cause local strains. Fig. 6 shows a furnace for ageing turbine castings. The temperature is about 1000 deg. F., and standard furnace construction is used, with semi refractory lining instead of firebrick. The charge cools slowly in the furnace. A yield of approximately 20 lbs. per KWH is secured.

CAST-IN IMMERSION UNITS

For babbitt, solder and tinning pots operating at 950 deg. F. and below, there has been on the market for about three years, a cast-in heating unit for immersion in the metal to be melted. This type of unit gives a higher operating efficiency than where the units are placed outside of the pot.

TIN PLATE

The cast-in immersion units have also been used to heat the pots used in the manufacture of tin plate. These units were installed in the standard pots. Approximately 100 KW is installed on the feed side and 25 KW on the discharge side. Approximately 4 KWH per base box is used. Half the heat on the feed side is on hand control, remaining on constantly,

FIG. 5

the other half is on automatic control. The advantages of electric heat are close temperature control, allowing the operator to give all his attention to feeding the material through, better heat insulation is possible, the pots get no hotter than the metal, eliminating possibility of cracking.

GALVANIZING

Galvanizing is a process that requires close control of temperature and uniform temperature throughout the tank.

A great deal of interest has been shown in electric heat for this process, and in the past two years

several electrically heated galvanizing tanks have been installed.

The tanks installed have covered quite a variety of work, such as structural steel for outdoor substations, transmission line towers, etc., steel wire, castings, sheet metal parts, etc.

The tanks have varied in size from 17 in. wide x 36 in. long x 7 in. deep to 22 in. wide x 30 ft. 6 in. long x 4 ft. deep and the electrical ratings from 27 kw. to 405 kw.

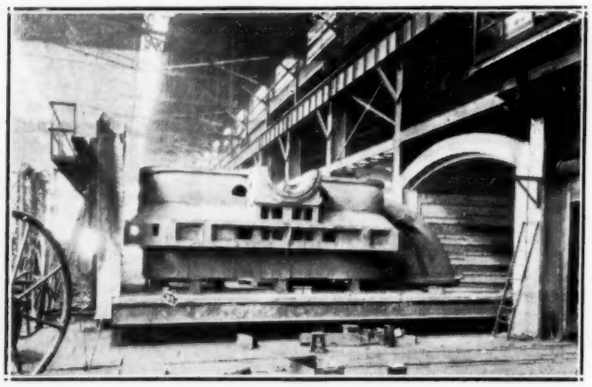


FIG. 6

The large tank referred to is shown on Fig 7 and some of the operating data is given below:

Lbs. of steel Galvanized per hour	KWH required per hour	KWH per ton of steel galvanized
2000	195	195
4000	260	130
6000	325	108
8000	390	98

The above power consumption is based on continuous operation.

The principal advantages of electrically heated galvanizing tanks are uniform and controlled temperatures, less dross, longer pot life, and improved working conditions.

JAPANNING

One of the most interesting installations of electrically heated japanning ovens is at the Wolverine Enameling Company.

There are four ovens of the intermittent conveyor type, having a total connected load of 554 kw. Each oven is 20 ft. long, 9 ft. wide.

The main baking units are two of the type "A" oven, set in tandem, one for first coat work and the other for second coat work. The ventilating air is forced through the oven counterflow to the work, therefore the incoming work is preheated by the outgoing hot air, and the outgoing work is cooled by the incoming air. This type of ventilating system not only makes it possible to reclaim a large percentage of the heat in the outgoing work, but also cools the outgoing work to a temperature at which it can be dipped for the second coat, or be handled.

The over-all length of the two ovens combined, including dip tanks, loading and unloading spaces, is a little over 200 ft. The interior section of the oven is 8 ft. 4 in. high and 9 ft. 10 in. wide. The total volume of the ovens is 14,000 cu. ft.

Both ovens are served by one continuous conveyor, 8 ft. 4 in. wide, with cross pipes spaced on 15 in. centers. The load is suspended from these pipes and the conveyor speed is approximately 16 in. per minute.

The ovens have a total connected load of 300 kw. The electrical heating units are located toward the top of the oven.

ELECTRICAL STEEL MELTING NEW FURNACES IN 1927

This list covers furnaces purchased or contracted for during 1927:

Number	Capacity	Total Tonnage
6	¼ ton	1½
7	½ ton	3½
3	1 ton	3
8	1½ ton	12
4	3 ton	12
1	8 ton	8
1	10 ton	10
30		50

Time of melting reduced by installing increased transformer capacity. Removable roof types have been tried but we have no positive statement as to their success. The carbon electrode is giving satisfactory work and no new types of electrodes have as yet appeared on the field to replace it.

ELECTRIC FURNACE LOSSES

As indicated above the trend of cost on electric arc melting furnaces is downward. There is still a great opportunity for a further reduction in costs

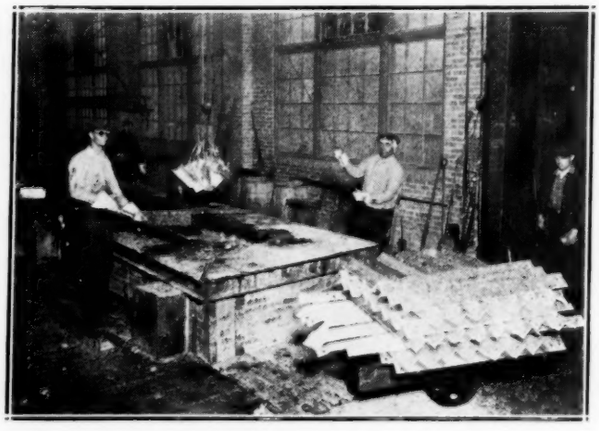


FIG. 7

by a study of the operating characteristics of melting equipment and accurate knowledge of the distribution of losses from the incoming power line through to the furnace during both melting and refining.

An article on this subject appeared in Stahl & Eisen of January 19, 1928, and gives some interesting figures from German and Austrian sources on the distribution of losses. While these figures may not be entirely accurate for American practice they indicate that from a cost of operation standpoint delays occurring during the refining time are costly.

Furnace Ratings:

In the consideration of new furnaces the methods of rating are of interest. Different manufacturers have different methods of rating melting furnaces and this causes some confusion when comparisons are attempted. Until a few years ago this condition existed in the ratings of mill motors.

Three methods being used now are as follows:

1. Diameter or furnace shell with KVA rating of the electrical equipment. These two figures give the definite mechanical and electrical limits of the furnace installation. The amount of metal which can be charged into the furnace is a function of the shell diameter. The rate at which the furnace will melt is a function of the capacity of the electrical equipment.
2. Holding capacity of the furnace. This method does not give a complete picture of the furnace, as the practice has changed materially in the past few years. Furnaces are now being run at twice the charge on which they were rated and operated several years ago. Under emergency conditions heats of several times the rating may be made. It is hardly practicable to rate the furnace in normal holding capacity as this figure varies under different practice and in different plants.
3. Production in tons per hour. This method of rating is subject to great variation as the actual rate of production is dependent on operating practice, which varies with practically every plant. This method of rating was developed for use on furnaces installed in foundries making acid castings and of course cannot be applied to basic operation.

Operating Data:

Operating data on any individual furnace to be of value must give a complete analysis of all the conditions surrounding the operation.

The compilation of this data on a sufficient number of furnaces to give an accurate picture of present practices would make an extremely lengthy report. It may be better to consider the average operation on a number of plants using several types of electric melting furnaces.

A summary on ten foundries making steel castings results in the following:

Smallest tonnage charge per month	420
Largest tonnage charge per month	845
Average tonnage per month	510
Highest power consumption per ton	687 KWH
Lowest power consumption per ton	548 KWH
Average power consumption per ton	607 KWH
Average electrode consumption per ton:	
Amarphous carbon	16 lbs.
Graphite	7½ lbs.

All the above figures are based on one month's actual operation and represent an average condition in the steel foundry industry that has obtained for the last three or four years, operation at 50% to 60% capacity.

These figures are improved by increased production as indicated by the following data on a particular furnace:

Furnace installed in Central New York
Is rated 5'0" diameter of shell, 350 KVA
Has normal holding capacity of 2,000 lbs.
Has melting rate of 1,000 lbs. per hour

Under a period of rush production in the foundry, which makes acid steel castings, this furnace produced:

At the rate of 75 heats per 5-24-hour days
Average charge per heat 1,800 lbs.
Actual production approximately 1,250 lbs. per hour
Power consumption 525 KWH per ton
Electrode consumption approximately 5½ lbs. graphite

Under present normal conditions, when this furnace is operating 6 to 9 heats per day the power consumption is approximately 550 KWH per ton and the electrode consumption 6½ lbs.

The general trend of operating costs in electric melting furnaces is downward. This is due to more intelligent operation, the use of higher melting voltage and higher melting rates, the standardizing of melting practice, etc.

Test on 25-Ton Heroult Electric Melting Furnace

KWH/Ton charge	508 KWH
KWH/Ton ingot	559 KWH
KWH/Ton melted	541 KWH
Pounds Electrode (graphite) per ton ingot	12 lbs.
Pounds Electrode (graphite) per ton melted	11½ lbs.
Metal to O. K. ingot	91 %
Furnace metal loss	61.2%
(Efficiency based on 331.5 KWH for 10% superheat and 100% efficiency)	
Average Monthly Power Factor	84.5%
Time—tap to top	5 to 7 hrs.

(Above figures from 30-day operation)

METHODS OF ELECTRIC WELDING

The art of electric welding is filling an indispensable place in modern industry. From an emergency repair tool it has become one of the valuable resources of designers and manufacturers, permitting the use of wrought steel parts having the advantage of maximum strength and reliability with minimum weight to such an extent that hardly a branch of manufacturing is conducted at the present time but what has taken advantage of welding to produce a superior product.

It is altogether fitting that the Electric Heat Committee of the Association of Iron and Steel Electrical Engineers should include in its annual report a record of the progress of this important field of electrical engineering. In recording the progress of this art for the past year, and including it in the report of the Committee for the first time, it becomes desirable to review the field of electric welding prior to the beginning of the period covered by this report in order to provide a background for future consideration of progress in this field.

Welding as a process did not depend upon the discovery of electricity, but was practiced long before the laws of electricity were well known. The blacksmith heated two pieces of iron in his forge and welded it on the anvil in a very picturesque and laborious manner, and we correctly think of the blacksmith as being a man of unusual physical accomplishments. He heated the material to be welded in the reducing atmosphere of a fuel-fired furnace up to a plastic state, where the two pieces were united by blows of the hammer. There was no material added to the weld; consequently there was no problem of change in analysis, except as carbon might be added from the forge. The metallurgical structure of the weld was controlled by

quenching, and was a function of the blacksmith's skill. Welding in this form was indeed a mechanical art.

In addition to the old type of forge welding there have been developed in comparatively recent years several methods of welding, including (1) the electric arc, (2) the resistance process, (3) the atomic hydrogen process, (4) the oxy-acetylene process, and (5) the thermit process. Inasmuch as it is the function of this Committee to report progress in the electrical application in the steel industry, this report will confine itself to the consideration of electric welding methods only.

Electric Arc Welding

The electric arc has been known ever since the early part of the nineteenth century and for a long period of time has been used for the electric arc welding process. In this process the heat of the electric arc causes the melting of the metals to be added as well as the melting of the work to be welded. In this molten condition, the two metals unite to form what really amounts to a cast joint. Two applications of electric arc welding are more or less commonly practiced. One is the metallic arc process and the other the carbon arc process. In the former process the electrode and filler rod are one, whereas in the carbon arc process the carbon is the electrode and the filler rod is melted in the heat of the arc between the carbon electrode and the work. The former process, however, is the more common.

Resistance Welding

Resistance welding was discovered by Professor Elihu Thomson about forty years ago. It resembled the old forge method of welding perhaps more closely than any other method, since it does not bring the material to be welded to the melting point but merely to the plastic stage. The heat required to accomplish this is generated in the material itself by passing a current through the material. A large part of the resistance necessary to generate this heat is found in the contact between the electrode or dies and the pieces to be welded, or between the pieces to be welded. This resistance, however, is relatively low, and consequently a low voltage is all that is necessary to accomplish the weld. On account of the difficulties of transmitting current at low voltages, it has become the exclusive practice of resistance welding to use alternating current, transforming the power from line voltage to the required welding voltage right at the welding machine. After the metal has been brought to a plastic state by passing electric current through it, a high pressure is applied and the plastic metals weld. This pressure in a certain way resembles and corresponds to the forging on the blacksmith's anvil.

Atomic Hydrogen Welding

The atomic hydrogen process of welding is one of the newest, and is still in its infancy. Essentially, this process consists of passing a stream of hydrogen through an electric arc, where the intense heat of the arc transforms the hydrogen from molecular to atomic state. After leaving the arc, the hydrogen recombines from atomic to molecular form, giving up heat at a very high rate. The welding is accomplished by melting the filler and material to be welded in this region where the transformation occurs where the high temperature and reducing atmosphere provide favorable conditions for a strong ductile union between the two metals. The possibilities of the welding process have just begun to be investigated commercially and the indications are that it has an important though possibly limited field.

ELECTRIC WELDING EQUIPMENT

Arc Welding Equipment

For electric arc welding with either the metal or carbon electrode processes, direct current power has been almost universally accepted. It is desirable in welding to maintain as short an arc as possible, especially in the metal arc process. This is to make the shortest possible path between the melting and vaporizing of the material at the electrode tips and its contact and dissolution in the pool of molten metal in the work, since in this finely divided state the electrode material is readily oxidized and the dissolving of oxide in the weld produces weaknesses. For most metal arc welding, voltages of 20 to 25 volts have been recognized as more suitable. These voltages, however, are too low to readily strike an arc. In the carbon arc process, a slightly higher voltage is generally used. This can be done without undesirable results since the metal filler rod may be held as near to the work as necessary to shorten up the path between the filler rod and the work. Furthermore, with the carbon arc process the electrode material is not vaporized, but it is melted or fused, and in this fused state it is not necessarily so finely divided as in the vaporized state incident to the metallic arc process.

In both the case of the 20-25 volt metallic arc and the 35-40 volt carbon arc, used also for bright electrode wire welding, it is desirable to have a somewhat higher voltage for striking the arc than is necessary for maintaining it.

This variable potential for operating and starting has been provided in several different ways. One common method is to so design the machine that it has an open circuit voltage of approximately 60 volts, and so designed that the armature reaction will drop the terminal voltage from 60 to 20 or 25 when the desired welding current is flowing in the armature. Since the welding voltage should be the same for any desired value of current, it becomes necessary to provide some means of adjusting the machine so that different values of armature currents produce the same drop in terminal voltage. This is accomplished by means of shifting a pair of the brushes on the commutator. This means of adjustment is very flexible and makes it possible to obtain an infinite number of welding currents. This type of motor generator is shown in Fig. 8.

One other common method of obtaining the desired voltage regulation at the arc employs a direct current generator of constant potential. The drop in voltage at the arc is accomplished by inserting an adjustable resistance between the generator and the welding arc. This resistance is so chosen that when the desired welding current is flowing, the drop in potential will bring the arc voltage down to the desired value. The process is commonly referred to as the constant voltage method, and the former process as the variable voltage method. The former method makes it necessary to have one motor generator for

each operator, and the latter system of supplying power is adaptable to the requirements of several operators welding simultaneously.

Reactor

It is desirable to provide an inductance in the welding circuit of either constant potential or variable voltage methods of welding to assist in maintaining a steady arc. This device, called a reactor, consists of a coil surrounding a magnetic circuit, so designed that the permeability of the circuit as a whole is nearly constant over the full range of welding current.

Electrodes

The metal arc welding electrode has the dual function of filler rod and electrode. In either of these capacities it has many conditions to meet. As

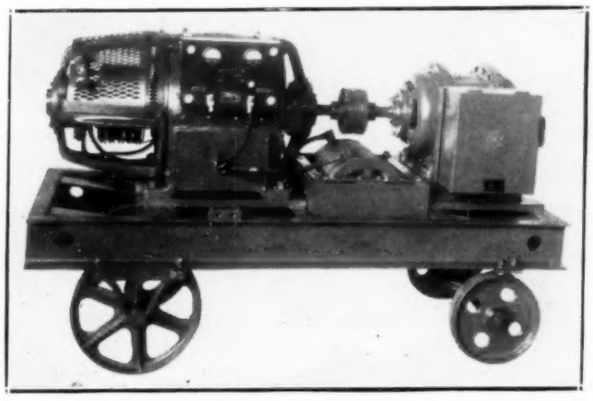


FIG. 8.

an electrode it must be capable of supplying a steady stream of electrons to maintain the arc, which means that it must have a low surface tension and must have some component which is easily vaporized, this latter condition being met by providing a slag, impurities or iron oxide. Carbon is advantageous from the standpoint of supporting the conductivity of the arc as well as manganese, but the former is open to the objection that its oxide is a gas, whereas the latter enjoys the advantage of a solid oxide which readily dissolves in the slag and has no tendency to produce blow holes. In addition to supporting the arc, the electrode must supply the filler material for the weld. Iron oxide which operates as a stabilizing agent in the arc is undesirable if included in the weld, making the latter brittle and weak. It is, therefore, necessary to provide a slag to dissolve the oxide and prevent its inclusion. It is needless to say that the manufacture of electrode material to satisfactorily meet all these conditions is a very difficult task.

Atomic Hydrogen Welding Equipment

The arc required for the atomic hydrogen process is maintained between two tungsten electrodes. The characteristics of the hydrogen gas are such that approximately 300 volts is required for striking and 60 to 90 volts for maintaining the arc. In order to stabilize the arc, as well as to control the energy developed by the arc, it is necessary to include a reactor in the arc circuit. This reactor is adjustable by means of a movable armature to values of current from 30 to 80 amperes. A special electrode holder provides means for adjustment of the arc between the electrodes by the operator and for guiding the flow of hydrogen gas into the arc. The work is melted by the atomic hydrogen flame and the filler rod is melted in the same flame and added to the work.

The welding equipment required for the atomic hydrogen process then consists of an electrode holder, a transformer, and adjustable reactor with necessary control equipment and a supply of hydrogen.

MATERIALS SUITED TO WELDING

The range of materials suited to welding varies somewhat depending upon the particular welding process considered. Virtually the entire range of the carbon steels can be welded but the physical properties of the weld metal are more nearly comparable with those of the material welded, in the case of steels where the carbon content is below 0.30%. This includes tensile strength, ductility, and freedom from porosity.

Metallurgical studies have shown that a segregation of a certain portion of the carbon in the parent metal occurs in a narrow band alongside the fusion zone in the parent metal. The amount of this segregation varies with the temperature gradient of the welding operation and also the carbon content of the plate material being welded. Just what this variation amounts to is not known, but it does not impair the physical properties of the weld on steels below 0.30% carbon. The amount of segregation is also effected by other impurities in the parent metal.

Steels such as locomotive firebox steel and flange quality steel, corresponding to A. S. T. M. specification A-30, which contain 0.20% carbon and 0.40% manganese with phosphorus and sulphur not over 0.05% each, are best for arc welding where good jhysical properties of strength and ductibility of the welds are desired. A. S. T. M. specification A-78 and S. A. E. specification No. 1010 are also satisfactory grades of steel for arc welding. In general, with the low carbon steels whose strength varies from 50,000 pounds per square inch to 60,000 pounds, and whose ductibility is from 25% to 30% elongation in 8 inches, the weld will be equal to or stronger than the plate material and its elongation will vary from approximately 25% to 50% of that of the plate material itself, when the automatic welding process is used. With the hand welding process this ductility will vary from 20% to 25% of that of the plate material welded. With the higher carbon steels the weld metal is rendered more brittle by the absorption of carbon from the steel, and while the strength of the weld will in many cases be very satisfactory, the ductility is very much reduced by the brittleness caused by the carbon.

At the present time some arc welding is being done on the chrome steels. The nickel chrome steels are also welded with the arc process. In general, the welding of the alloy steels is accomplished with varying degrees of success depending upon the alloying elements and the purpose for which the material is being used.

When it comes to welding alloy steels, such as nickel and chromium steels, the weldability becomes even more difficult to define. Most of these steels

can be welded in the sense that a fusion between the two parts can be accomplished, but the quality of the weld is not uniformly satisfactory and the ductility is likely to be poor. Certain metals, such as aluminum, are very easily oxidized and a satisfactory electrical weld is only accomplished in the absence of an oxidizing atmosphere. Other metals, such as brass, which may be an alloy of two other metals having widely different metling points, offer the difficulty that the weld must be accomplished without vaporizing the metal of the lower boiling point, as in the case of brass, or zinc. In addition, these metals are often readily oxidized and it is desirable to weld them in the absence of oxygen or even in the presence of a reducing atmosphere. Copper offers the difficulty that it is a very good conductor of heat and it is difficult to concentrated a sufficient amount of energy in the metal to effect a weld. Galvanized iron, strangely enough, can be quite readily welded. The nickel chromium and monel metal may be welded, but the monel metal welds lack ductility even when accomplished in a reducing atmosphere, and under seemingly favorable conditions. Normalizing could restore to a certain extent the original physical properties but adds a complication in cases where the size of the object to be welded makes a suitable normalizing furnace prohibitive, both from the standpoint of investment and operating costs.

When it comes to welding dissimilar metals, it is difficult to effect a union in combinations where the melting points of the two pieces involved are widely different. For instance, aluminum cannot be welded to any other metal by any known process. Zinc cannot be welded to any other metal; neither can lead. Many other combinations can be effected only by certain processes. In the welding of dissimilar metals the resistance method of welding has an inherent advantage over the fusion welding processes inasmuch as the weld is effected at a temperature lower than the melting point of either metal. Furthermore, since the weld is accomplished between two pieces the hot metal is not exposed to the atmosphere to any great extent. It is even possible that the resistance welds are accomplished in the presence of a reducing atmosphere due to the temperature of the weld causing some of the dissolved gases to be driven off. The most common of the dissolved gases is hydrogen.

Thickness

The maximum thickness of steel plates now being commercially welded by the automatic arc process is used in the manufacture of tanks and pipe exclusive of pressure vessels is 5/8". Greater thicknesses than this are sometimes welded by hand welding processes but the technique for machine welding of greater thicnesses has not been completely worked out in detail. For high pressure high temperature work, thicknesses of plate up to 3 inches have been welded. For tank and pipe work the thicknesses of steel plate below 5/8" are extensively used, and considerable work is now being done on heavier plates for fabricated steel structures, replacing riveted construction.

One consideration in discussing the weldability of different metals by the resistance welding process is the resistivity of the metals involved and their respective thicknesses. In using the projection welding process it is not feasible to weld steel sheets thinner than number 18 gauge, since the metal is not strong enough to stand up under the required pressure. In other forms of resistance welding the concentration of heat is controlled by the area of the die in contact with the metal. The thicker piece or the piece having the lower resistivity requires a smaller die and the thinner pieces of higher resistivity may be handled with dies of larger cross section. In general, the resistance method of welding except projection welding, is adaptable to thinner metals than arc welding. However, it is with difficulty that most metals below number 28 gauge or metals thicker than 3/8" total are welded by the resistance process. Individual cases where thinner metals and thicker metals have been welded can undoubtedly be cited, however.

With the metal arc process it is difficult to weld gauges thinner than number 18 on a lap weld or butt weld and still more difficult to make an edge-weld on the thin gauge by the metal arc process. However, the carbon arc can be applied to good advantage on edgewelds involving fairly thin gauges, the carbon arc melting the edges of the two pieces to be joined and causing the fusion of the edges, no material being added to the weld.

The atomic hydrogen process is seemingly adaptable over a range of sizes somewhat thinner than the metallic arc.

The speed of the welding operation depends upon the plate thickness, preparation of the joint to be welded, electrode, welding current, and the quality of weld desired. Also, the speed of welding will vary depending upon the nature of the material being welded.

The average speeds of welding for the various thicknesses of low carbon (below 0.30%) plate are as follows.

Thickness	Speed (Ft. per hr.)	
5/8"	15-20	double arc
1/2"	20-22	double arc
3/8"	25-30	double arc
1/4"	20-30	single arc
3/16"	25-35	single arc
1/8"	30-40	single arc

The above figures are for automatic welding and the corresponding speeds for hand welding may be taken as from 1/5 to 1/4 of the above.

TYPES OF ELECTRICALLY WELDED JOINTS

Three types of welded joints are commonly used in arc and atomic hydrogen welding. The butt weld is one in which two pieces of metal are placed end to end and a joint is effected by melting these two pieces at the joints, and adding a sufficient amount of material from either a filler rod or the metallic electrode. The lap weld is one in which the two pieces to be joined are overlapped and the edge of one piece welded to the side of the other, either with the addition of metals as is the case with a metallic arc weld, or simply by melting the edge of one piece as in the case of atomic hydrogen or carbon arc processes. The edge weld is one which may also be accomplished either with the addition of metal as in the case of the metal arc weld or simply by melting the two pieces to be welded as is generally

the case with the carbon arc or atomic hydrogen process.

These same types of joints may be made by resistance welding. In resistance welding, the butt weld is accomplished by the contact between the two pieces of metal, clamped in a welding machine and pressed together, the current flowing between the contacts of the two pieces, generating enough heat to cause fusion along this edge. The machine supplies the pressure required to force them together. The lap weld made with resistance type of welding, may be of the spot or line weld type or the projection weld type. Spot weld is made by clamping the metal between two dies and passing electric current through these dies concentrating the heat in the metal underneath them and raising the metals to the plastic point where the pressure of the dies causes a union of the two parts. In projection welding, one of the parts is punched so as to produce a projection which bears against the other. In this case, the concentration of the heating is affected by the projection and the dies do not need to be tapered. This makes the process more economical, reducing the upkeep on the die. In addition, the punching process has the added advantage that the scale which in the spot welding process might give trouble on account of its high resistance, is removed.

Furthermore, the projection type of welding has proved itself to be admirably adapted to the multiple weld process, from 6 to 30 projection welds having been made at one time. A lap weld may also be made by the seam process in the form of a seam weld, which is practically a continuous spot weld. In this case, the two pieces to be welded are rolled between two copper wheels under high pressure, and the current conducted through the material under these conditions, bringing the metal to a plastic state and effecting a union of the two pieces. This process has also been modified, even as the spot welding process is modified, by making a projection in one of the pieces to be welded in the form of a ridge. With this modification, the heat is concentrated at the line where the weld is desired, that is, at the ridge. It is not necessary to have wedge-shaped edges on the rolls. Due to the high pressure required on these copper rolls, their reconditioning is an important item in the operation of this type of welding machine.

The applications of welding are many, and as steel is finding wider and wider markets, and as it is replacing other materials of construction, so welding is finding a wider and wider field of application. The designing of automatic machines for accomplishing welding has greatly assisted in the conquest of the field.

AUTOMATIC WELDING HEAD

Perhaps no single contributing cause is more important to the rapid development of the popularity of the welding process to manufacturing than the automatic welding machines which have been designed. These have eliminated to a considerable extent the human element. In arc welding the most important single feature of the welding machine and the part common to all such machines is the automatic welding head. For automatic metallic arc welding a device is needed to automatically feed the electrode into the weld at the proper rate. The automatic welding head with its control panel is designed to accomplish this result. Figure 9 shows one view of this device. It consists of a pair of rollers which are knurled so that they grip the electrodes, suitable reduction gear mechanism, two magnetic cone clutches, and a driving motor. Each of the two cones on the horizontal shaft has an electro-magnet which when energized causes the cone to engage with a cone on the vertical shaft. These horizontal cones are rigidly keyed to the shaft in such a way and such a distance apart as to permit their engaging with the vertical cones with very little motion, one being arranged to drive the vertical cone in one direction and the other in the reverse

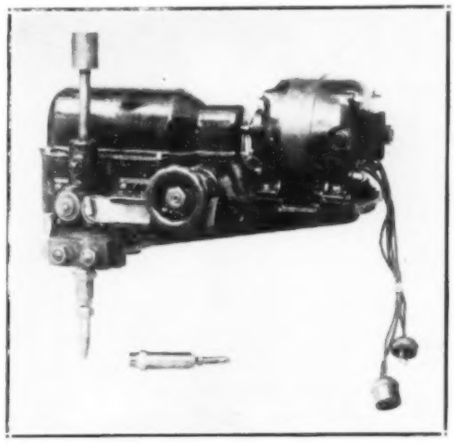


FIG. 9

direction. The advance or withdrawal of the wire is affected by the electro-magnet controlling this cone clutch.

The automatic control of the wire feed is arranged to maintain constant arc voltage, or in other words, a substantially constant length of arc. A contact-making voltmeter or voltage relay, operating on arc voltage makes the necessary electrical connections to energize one or the other of the magnetic clutches to regulate the feed of the wire for this condition. This type of control has its quick action made possible by the very low inertia of the moving parts. Since the motor is running at constant speed in one direction for either direction of wire feed, the inertia of the motor does not enter into the problem, the vertical cone and the reduction gear being the only part whose direction of rotation is changed.

The speed of the feed motor is so adjusted in ordinary operation that after the arc is established, the electrode is fed in by a series of very short rapid advances at approximately the rate at which the electrode is consumed, so that it is not necessary to withdraw the wire. A wide range of feed speeds are available by means of 2 to 1 speed adjustment of the feed motor and by a number of selected speed reductions obtainable in the welding head. The automatic welding head is designed to operate from a source of constant potential, the most usual source being the 60 volt constant potential generator that supplies the welding current. In the absence of this constant potential welding motor generator as in the case when the welding energy is supplied by a variable voltage machine, it is usually necessary to sup-

ply a small motor generator set for use with the welding head.

A large number of special welding machines have been devised for special application, the most common of which divide themselves into two different classes, depending on whether the seam is circular or straight. The automatic arc welding machine most commonly applied to welding a straight seam is the horizontal seam welder shown in Fig. 10. This machine is adapted to welding horizontal butt joints in tanks or pipes. A complete line of such automatic machines has been developed. The joint to be welded is firmly held in a clamp consisting of two upper beams, one along each side joint, and a lower beam directly beneath the joint.

The edges of the two upper beams are formed by two heavy copper strips. On top of the lower beam there is also a heavy copper strip called a backing-up bar. This is so arranged that the metal may be clamped between this bar and the two upper beams by applying air pressure to the machine. In this way the work is held firmly in place during the welding period. The welding head just described is

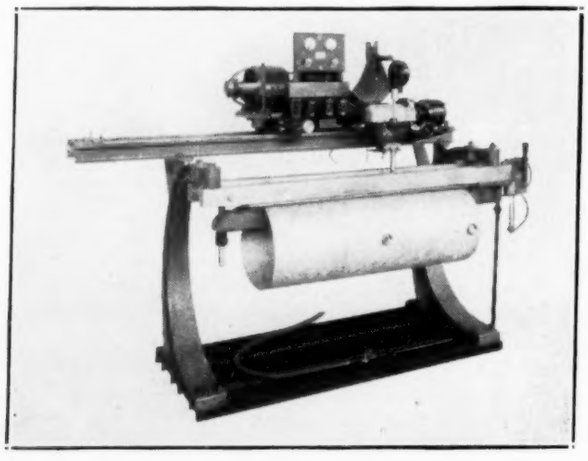


FIG. 10

mounted on a travel carriage in such a way as to provide motion for the electrode along the seam to be welded. This travel carriage is mounted on tracks parallel to the seam to be welded and the rate of motion along this track is controlled by changing the speed of the travel carriage motors. In the lower beam just below the copper backing-up bar is a copper conductor through which part of the welding current passes. The current flowing in this conductor establishes a magnetic field which stabilizes and guides the arc along the seam. Machines of the type just described are built to accommodate pipe or tanks varying from 5 inches in diameter and 2 feet long, made of 18 or 20 gauge sheets, to heavy steel pipe 7 feet in diameter and 36 feet long, made of 5/8-inch steel plate.

For automatically welding horizontal seams of steel plate in the fabrication of welded steel parts, the automatic welding head and travel carriage equipped in a similar manner as described above, may be used. The work is generally clamped in place but need not be if it is sufficiently heavy to hold itself in line without clamps. The requirement to be fulfilled is that the seams line up evenly and tightly parallel to the tracks on which the travel carriage is mounted.

There has also been designed a circular seam welder which has found rather wide application, as in the construction of range boilers. For welding circular seams the automatic welding head is usually held stationary and the pipe or tank rotated, so that the seam to be welded passes under the welding head. The rotating device may be either the turntable type where the work is held in a vertical position, or the rolling type where the work is held in a vertical position, or the rolling type where the work is in a horizontal position. Occasionally work has to be welded that is so large as to make it undesirable to provide a moving table on which to mount it, and it becomes less expensive to move the welding head.

There are many variations of these automatic welding machines, each to suit some particular application. The essential part of any automatic welder consists of the automatic welding head and its control, a suitable clamping device for holding the work in position, and a travel mechanism for moving either the work or the welding head. The requirements to be fulfilled in any automatic welder are that the joints be accurately and evenly lined up so that the fused area will be equally distributed in the edge to be welded, and a strong joint will result.

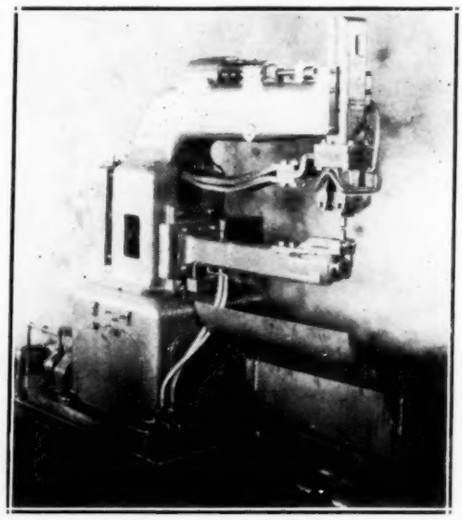


FIG. 11.

Many forms of automatic resistance welding machines have been developed. An automatic machine for making six projection welds joining two steel cups, is on the market. This is one of the recent developments of resistance welding. This machine welds at the rate of 16 pieces per minute or nearly 1,000 per hour, each piece containing six separate welds. Two operators are required, one to work on the die and the other to remove the finished piece. The welds are quite uniform and are very good quality. Another very interesting form of automatic resistance welding machine is designed for the welding of barrels and will handle clean material up to a maximum capacity of two pieces of number 16 gauge, pressure type welds being made on full fin-

ished sheets without extra preparation. The welding is accomplished at the rate of 10 to 40 feet per minute. The lower die is a copper bar inset and the upper has a tire 12 inches in diameter and 1½ inches thick, clamped to a thoroughly water-cooled mandrel. It is estimated that a machine of this type can produce from 80 to 120 55-gallon drums per hour, depending on the preparation of the material for welding, the normal speed being 20 feet per minute for 16 gauge and 25 feet per minute for 18 gauge stock. A universal resistance welding machine is shown in Fig. 11. The head of this machine may be equipped with spot welding dies, horizontal seam welding rollers, or circular seam welding rollers, depending on the type of work required.

APPLICATIONS

There have been so many applications of welding to industry in the past year that it is hard to select the outstanding ones. Welding has been applied to a considerable extent in the fabrication of building frames. In this field it offers the attraction that it is relatively noiseless when compared with the riveted method of assembly. Since the steel frame buildings are largely in localities where population is dense, the noise is a very disagreeable feature of riveted construction. While several buildings have been built with nearly all-welded construction, it cannot be said that it is yet economical to use this method of fabrication in all parts of steel frames, a notable exception being lattice construction. However, steel trusses show a saving of 12 to 15%.

Furthermore, initial efforts to apply welding to building construction have met with the difficulty that the present rolled sections are designed especially for riveting and not necessarily the best sections for welded construction. In spite of this, trusses have been built and tested which have shown decidedly superior characteristics and at the same time have been less expensive than corresponding riveted construction. Welded construction offers the attraction of lighter weight, noiseless assembly and increased rigidity.

It cannot yet be predicted how far it may be practicable to go in welding structures but it is already certain that this method has many attractive features. A large number of tests have been made to determine the strength of the weld, but building codes have not yet generally accepted welding or precisely prescribed welding methods for building construction. A rigid inspection of welding methods is essential to safety but with such inspection and care on the part of the welder, its reliability is equal to that of riveting. Arc welding has proved its superiority for such applications as range boilers, a slight permium being paid for this type of construction. The application of arc welding to industry has been so broad that it is indeed difficult to indicate its field.

*High Tension Practice in Modern Plants**

By EUGENE VINET†

THE progress made in high tension practice has been so rapid in the last few years that one can hardly keep pace with the advances in this particular phase of the electrical business unless directly engaged in the work. While only two decades ago voltages of 66,000 and 110,000 volts were considered the height of attainment, today we are becoming so accustomed to such voltages that we consider them as ordinary. At present, high tension voltages can be considered as being 33,000 volts and above, although the day may soon be at hand where even 33,000 volts will be considered as a primary voltage for distribution purposes, especially in congested districts.

This paper which is intended to give a bird's eye view of the latest practice in high tension will deal only with such voltages as 33,000 volts and above, and only with step up and step down substations, including transformers, switching equipment and transmission lines which connect such substations.

Substations

Relatively little change has taken place within the last few years in the type of design of step up substations in so far as fundamentals are concerned. The chief accomplishment has probably been that of transformers so equipped as to change voltage taps under load, which is of particular use where large interconnected systems are in existence and the variation of load between peak load hours and off-peak load hours brings about considerable variations in the amount of energy to be handled by such systems. These transformers have two kinds of adjustments by which it is possible to change the ratio of transformation without interrupting the service. One is part of the transformer, and the other separate from the transformer. There are relatively simple arrangements which give sufficient elasticity to adjust themselves to all operating conditions, and while the cost of such transformers is approximately 30% higher, the benefits derived therefrom in a good many cases amply justify the additional expenditure. When the tap changing equipment is in a separate tank, the additional cost is approximately 50% higher.

Today the general practice is to use air cooled transformers in preference to water cooled transformers as used to be the tendency some few years ago. In this country we have not adopted to any extent the circulating oil system for transformers, although in certain countries of Europe such systems are much in vogue.

In the switching equipment, no radical departure has taken place either in air circuit breakers or oil circuit breakers. There have been a good many im-

*To be presented at A. I. & S. E. E. Annual Convention, June 25-28, 1928.

†Asst. to Vice Pres., Middle West Utilities Co., Chicago.

provements in so far as the detail of the mechanism of both types of switching is concerned, but the general design and lay out stands today practically as it was a few years ago. There are some instances where the European practice of synchronizing on the high tension side of transformers in preference to the low tension side is being followed, which is dictated largely through the preference of wishing to deal with low currents rather than high currents. Whether such synchronizing on the high tension side will become more the general practice in this country as time goes on is difficult to say at this time.

The switching is now almost entirely automatic with proper setting of relays according to the requirements of the operating system. In so far as the diagrammatic arrangement of substations, there is a tendency towards tying-in units of transformers with one particular line where several lines are in existence and operating them as single units rather than paralleling as used to be done some years ago. This naturally applies to the high tension system.

Transmission Lines

For transmission lines of voltages such as 33,000 and 66,000 volts, wood poles are still in general use. For higher voltages than 66,000 volts, it is fairly evenly divided between wood poles and steel tower construction up to 132,000 volts. Above such voltage, all lines are built on steel towers. The 33,000 volt line is of the pin type construction, and today the tendency is to use steel pins in preference to wood pins. There are a few companies using metallic arms, although the general practice is to employ wood cross arms. The framing of such lines is either of the triangular type with ridge pin on the top of the pole or with two cross arms, one conductor being on one arm, and two conductors on the other arm. Such construction has the advantage that if there is need for adding another circuit to the transmission line, this can be readily accomplished by the addition of another arm and placing the conductors of each circuit at the extremity of each cross arm.

As for 66,000 volt lines, there are still a few such lines built with pin type insulators, although the general tendency is to use suspension insulators. The so-called H-frame construction is frequently used for main or trunk lines. It consists of two poles with the cross arm at the top, and the conductors in a horizontal plane, and in suspension. This makes a particularly satisfactory type of construction, is reliable, inexpensive, and also offers the advantage that if it is desirable to place one or two ground wires above the conductors, it can be easily done.

In regard to 110,000 volt lines and 132,000 volt lines, most of these lines are built either on steel towers or on wood poles using the H-frame type of construction, with suspension insulators in either case. There are a few instances where metallic arms have been used on wood pole H-frame construction, but the general practice and tendency is to use the wood arm. The H-frame, wood pole construction is particularly well adapted for this type of line is cheaper than steel towers, and thoroughly reliable from every standpoint. It seems that unless lines are designed for carrying excessively heavy load, that the H-frame wood pole line is very well suited for this particular voltage. The 220,000 volt lines are all built on steel towers, and the spacing is such that the conductors are usually on a horizontal plane.

Research work which has been done in recent years in connection with lightning seems to have demonstrated beyond any doubt that a ground wire over transmission line conductors is a considerable protection against interruptions from lightning. This has been demonstrated experimentally and also in practice. One line which comes to my mind at this time, operating at a voltage of 132,000 volts, and which had been in service for three years without a ground wire, had 20 to 30 interruptions per year on the average due to lightning, and since two ground wires have been added to the line these interruptions have been reduced to approximately one to two per year. The reason why so many operators came to discard and have prejudices against ground wires over transmission lines was largely owing to the fact that the design and the construction of such ground wires did not receive the attention that they were entitled to, and were not treated as carefully as the conductor itself. The result has been that owing to innumerable breakages and troubles, the use of the ground wire until recently had been almost universally discontinued. Today, however, realizing that the protection against lightning by such ground wires is beyond question, operating engineers are devoting more attention to the design and building of such ground wires over their lines in such a thorough and adequate way that the old time troubles are not likely to be repeated.

H-frame types of lines can easily be equipped with such ground wires by the addition of properly designed bayonets projecting above the pole, and such a ground wire can be properly fastened by means of adequate clamps, possibly in suspension, which gives it a slight motion and makes it more pliable and adjustable to storm and weather conditions.

Steel towers, are usually designed in such a way that the ground wire can readily be added to the line if not placed originally with the construction of the line.

The general type of insulators used is porcelain and of the so-called disk design. In the case of extremely high voltage such as 132,000 and 220,000 volts, discharge horns or rings are frequently used above the suspension clamp to which the conductor is attached for the purpose of cutting down the time lag for excessive surges and increasing the factor of safety of the insulators. As for conductors, copper is very generally used as a conductor for high tension lines, although steel reinforced aluminum cable is also used extensively and is particularly adapted for long span construction.

So much for the overhead high tension system.

What was said in connection with step up substations applies equally well to step down substations, although in a reverse condition.

The great increase in density of load in congested districts, such as large cities or manufacturing centers, has necessitated the handling of energy on such large scales that it has become necessary to use high voltages for reaching distribution centers in such districts. In addition to being under certain conditions a source of danger, overhead systems

have other objections, so that the underground phase of high tension has had to receive considerable attention, and the manufacturers of underground cables have developed high tension cables which are highly satisfactory. There are installations in some of the larger cities of this country as well as Europe where underground cables are in operation at 132,000 volts. These high tension cables up to 66,000 volts are built either for single conductors or three conductors. For 132,000 volts so far the practice has been to use single conductor cables, and the hollow type conductor has proved to be the preferred type.

In densely populated centers, high tension transmission systems are now partly overhead and partly underground. With recent improvements in the design of underground cables, and the necessity for interchange of energy between generating stations where the load diversity is such as to justify an interconnected system, the tendency will undoubtedly be towards further underground high voltage systems. In widely scattered territories where interconnection of generating plants is necessary for economic reasons, there is constant need for further improvements in overhead high tension practice.

Final Outline Dimensions for Association of Iron & Steel Electrical Engineers Standardized Mill Type Motor—June, 1st, 1928

A. C. CUMMINS, Chairman Standardization Committee

THE Membership may recall that the dimensions for the Standardized Mill Type Motor were first published in considerable haste, because one manufacturer desired to immediately place on the market motors built to the Association's requirements. As a result of this effort to effect an early publication of the data, some minor errors in the records of the Committee were not discovered until after the original publication of the dimensions. The Committee wishes, at this time, to republish the dimensions in their final corrected form, and to enumerate the changes found necessary.

These changes are as follows:

(1) The Dimension "XA" will hereafter refer to the diameter of the motor pinion bore at the large end of the taper. In the previous published dimensions, "XA" referred to the diameter of the armature shaft for sleeve bearings only.

(2) A note has been added stating that armature shaft diameters for sleeve type bearings will be the nearest ⅛" to the diameter required for roller bearing applications.

(3) On account of a typographical error, the gear ratio of the 15 HP ("C" Frame) was not correct. The correct dimension is 4.95" instead of 5.05" as previously published.

(4) Dimension "QQ", the axial length of the jackshaft bearing housing is now indicated as an approximate minimum dimension, for two reasons:

(1) The inner surface of the jackshaft bearing housing need not be machined and therefore the dimension will vary slightly due to the irregularities of the casting.

(2) Dimension "QQ" is a minimum dimension in order that there may be no question that the axle shaft bearing housing will receive sleeve or roller bearing capsules of all manufacturers interchangeably.

(5) A note has been added, stating that "MM", the outside diameter of the jackshaft bearing capsule, applies to both roller and sleeve bearings. This will enable the manufacturer to apply either type of bearing to the same frame without changing machining dimensions.

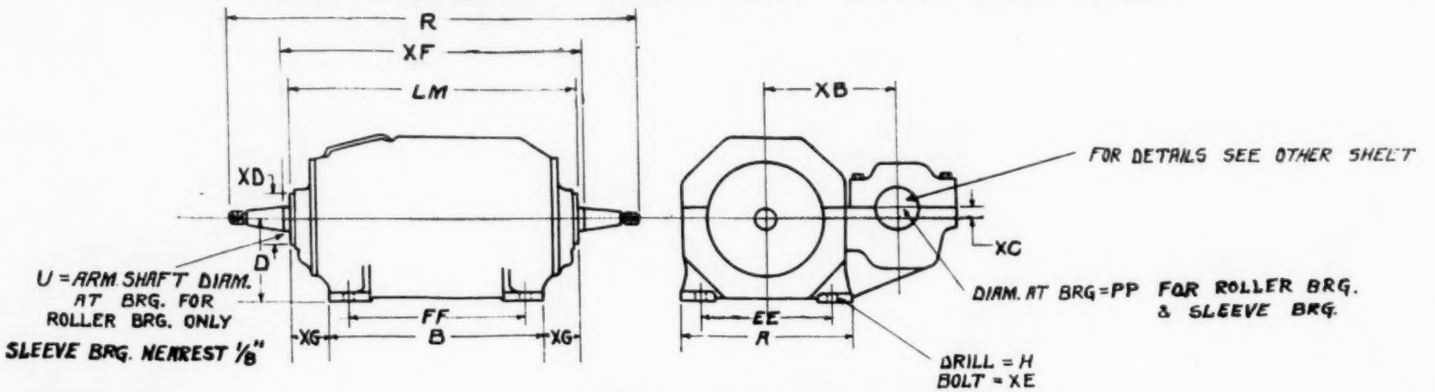
(6) On our previously published list of dimensions, we stated that "SS" was the diameter of the jackshaft sleeve bearing. In order to make jackshafts interchangeable with either sleeve or roller bearings, it has been deemed desirable to omit this note, indicating instead that Dimension "PP" is the diameter of the jackshaft for either sleeve or roller bearings, and that Dimension "SS", is the diameter of either type of shaft in the gear or pinion fit.

(7) Dimension "KK" is made an approximate dimension on the final published details, due to the fact that this inner surface need not be a machined surface and therefore is subject to slight variations.

The Committee submits this list of changes, together with a republication of the complete set of standardized dimension, with the suggestion that in all future dealings with the matter of Mill Type Motor Standardization, reference will be made only to dimensions as published by the Association in June, 1928.

A.I.&S.E.E. STANDARDIZED INTERPOLE MILL MOTOR DIMENSIONS

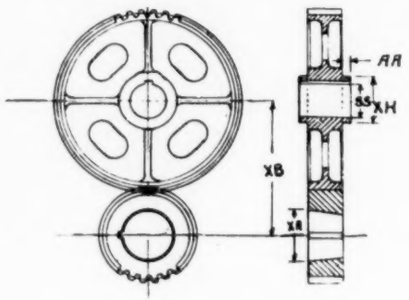
COMPILED BY STANDARDIZATION COMMITTEE A.I.&S.E.E. JAN.-13-1927 REVISED MAY 5-'28



FRAME NO	RATING & SPEED +MILL HP	RPM	‡CRANE HP	RPM	TORQUE LB. FT. MILL	CRANE	GEAR RATIO STD.
A	7½	800	10	690	49	76	4.94
B	10	725	13	625	72	109	4.94
C	15	650	20	560	121	188	4.95
D	25	575	33	495	228	350	4.94
E	35	525	45	455	350	520	4.94
F	50	500	65	430	525	795	5.05
G	75	475	100	410	830	1280	5.05

OVERALL DIMENSIONS IN INCHES

FRAME NO	EE	A	FF	B	D	XB	LM	XF	R	PINION FACE	PINION PITCH	ARM. SHAFT KEY WIDTH	ARM. SHAFT KEY HEIGHT	AXLE SHAFT KEY WIDTH	AXLE SHAFT KEY HEIGHT	H	XE	SS	U	XG	XC	FRAME NO
A	14	17	18	21	8½	12.625	29	30	39¼	3½	4	½	½	¾	½	25/32	⅞	3⅛	2.1654	4	1	A
B	15	18	19	22	9	13.375	31	32	41¼	3½	4	½	½	¾	½	25/32	⅞	3½	2.1654	4½	1	B
C	16½	20	21	24½	10	14.875	34	35	45¼	4	4	½	½	1	¾	1 1/32	1	3⅞	2.5591	4¾	1⅛	C
D	18¾	22¾	24¾	28½	11¼	16.833	39	40	51½	4½	3	¾	½	1	¾	1 3/16	1⅛	4⅜	3.1496	5¼	1⅛	D
E	20½	24½	26	30½	12¼	17.833	42½	43½	55½	4½	3	¾	½	1	¾	1 3/16	1⅛	4⅜	3.3465	6	1⅛	E
F	22½	27	28½	33	13⅜	19.166	47	48	61	5	3	¾	½	1¼	⅞	1 5/16	1¼	5⅛	3.7402	7	1¼	F
G	25	30	32	37½	14¾	21.800	52½	53½	66¾	5	2½	1	¾	1½	1	1 9/16	1½	5⅞	4.3307	7½	1¼	G



NOTES

+MILL RATING (BASIC RATING) 1HR. CONTINUOUS RUN TEMP. = 75°C

‡CRANE " (APPROX. ONLY) ½ HR. " RUN TEMP. = 75°C.

Δ = LIMITING DIMENSION

STANDARD SHAFT TAPER = 1.25" PER FOOT

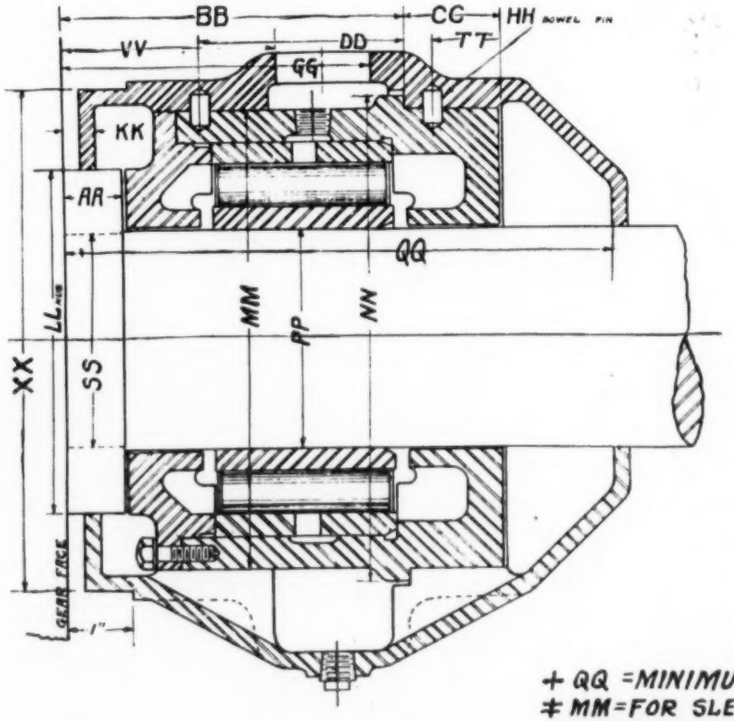
" " NUTS = 8 THREADS PER INCH

KEYWAY TO BE CUT PARALLEL TO TAPER - CUTTER TO BE RUN OUT.

FRAME NO	XD	XA	XH	ANTI-FRICTION BRG. NO.	STANDARD GEAR PINION	GEAR	RATIO PITCH	Δ GEAR BELOW	CASE BRSE	FRAME NO
A	5½	2	5	311	17	84	4		2½	A
B	5½	2	5½	311	18	89	4		2⅝	B
C	6¼	2½	6	313	20	99	4		2¾	C
D	7¼	3	6½	316	17	84	3		3¼	D
E	8	3¼	7	317	18	89	3		3	E
F	8¾	3⅝	8	319	19	96	3		3	F
G	10	4¼	9	322	18	91	2½		4¼	G

A.I.&S.E.E. STANDARDIZED MILL MOTOR AXLE-SHAFT DETAILS

COMPILED BY STANDARDIZATION COMM. A.I.&S.E.E. JAN. 11, 1921. REVISED MAY 5, '26



FRAME NO.	MOTOR H.P.	AA	BB	CC	DD	TT	VV	GG	HH	* KK	LL	# MM	NN	PP	FRAME NO.
		DIMENSIONS IN INCHES.													
A	7½	⅞	5	1⅜	2⅞	½	3	4½	⅜	½	5	6.500	7	3.1496	A
B	10	1	5⅜	1½	3⅛	½	3⅜	4⅝	⅜	½	5½	7.3125	7¾	3.5433	B
C	15	1	5⅞	1¾	3½	½	3⅝	5⅛	⅜	½	6	8.125	8⅝	3.9370	C
D	25	1⅛	6⅜	2	3⅞	⅝	4	5½	½	9/16	6½	9.125	9⅝	4.3307	D
E	35	1⅛	6⅞	2	4½	⅝	4⅜	5⅞	½	9/16	7	9.750	10¼	4.7244	E
F	50	1¼	7½	2¼	4⅞	¾	4¾	6¼	½	9/16	8	10.375	10⅞	5.1181	F
G	75	1¼	8½	2½	5¾	¾	5½	7	½	9/16	9	12.000	12⅝	5.9055	G

FRAME NO.	+ QQ	SS	XX	ANTI-FRICTION BEARINGS 200 SERIES	300 SERIES
A	7¾	3⅛	7¾	W-216	313
B	8½	3½	8½	W-218	315
C	9¼	3⅞	9½	W-220	317
D	10¼	4⅝	10½	W-222	319
E	10⅞	4⅞	11¼	W-224	320
F	11⅞	5⅛	11⅞	W-226	321
G	13⅞	5⅞	13½	W-230	322

+ QQ = MINIMUM DIMENSION - APPROX.
# MM = FOR SLEEVE & ROLLER BRGS.
* KK = MAXIMUM DIMENSION - APPROX.

*Anti-Friction Bearings For Roll Necks**

By J. H. VAN CAMPEN†

DURING the past year a great amount of progress and a large number of applications have been made in applying anti-friction bearings on the roll necks of rolling mills. These anti-friction bearing applications are covering almost all types of rolling mills, rolling non-ferrous metals as well as steel. Some are more or less experimental, but the great majority are successfully performing the duty for which they were installed.

There are four types of anti-friction bearings used on roll necks, namely: Ball, Straight Roller, Taper Roller and Spherical Roller.

The success of roll neck anti-friction bearings depends practically upon three factors: (1) The selection of the proper type and size of bearing. (2) The proper mounting of the bearing on the roll neck. (3) The lubrication of the bearing.

In selecting the proper type and size bearing you are controlled by certain limits, such as space limitations, which determine the maximum outside diameter of the bearing, and keeping the neck stresses within permissible limits, determining the diameter of the bearing bore. This, together with the loads

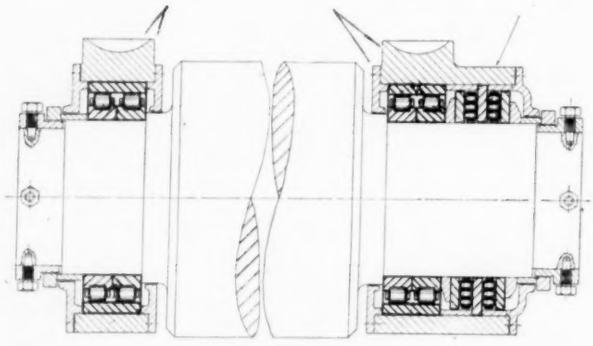


FIG. 1.

and speeds under which the bearing has to operate, are the controlling factors in selecting the proper type and size of bearing.

After determining the type and size of anti-friction bearing to be used on the roll neck under consideration, next comes the proper mounting of the bearing, which is of equal importance, as the selection of the proper type and size bearing alone does not necessarily mean that the installation shall be a successful one. The important factors to be considered are the machine tolerances or fit to be allowed between the outside diameter of the bearing and the bearing container, and also between the bearing bore and the roll neck, and the proper running clearance of the bearing, the conditions of service which determine the precaution to be taken in the proper sealing of the bearing from infiltration of foreign substances such as water, scale, and dirt which tend to work in, and the maintenance of lubrication within the bearing. Also the mounting of the bearing should permit the greatest ease in removing the bearing from the roll neck when changing rolls.

In the lubrication of anti-friction bearings for roll necks, care should be taken in selecting the proper lubricant. The factors covering this selection are the speed under which the bearing operates, the temperature, and if rolling material wet or dry.

Of the various types of mills, the backed up type such as the Cluster Mill and the Four-High Mill offer the best conditions for anti-friction bearing applications, as the allowable space limits are greater than any other type of mill. Next comes the Two-High Mill, and last the Three-High Mill. The greatest percentage of anti-friction bearing applications to date have been made on the backed up type of mills.

On existing mills, the problem of installing anti-friction bearings offers greater difficulties than on

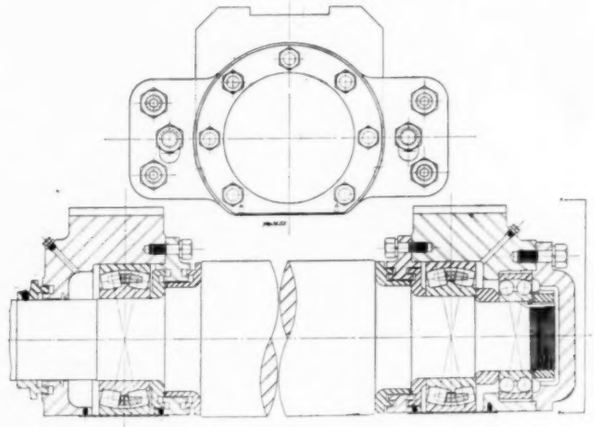


FIG. 2

new mills, as in new mills the design of the rolls and mill housings can be made to better accommodate the bearings.

The following will illustrate various types of anti-friction bearings, as applied to roll necks.

Figure 1 illustrates a typical mounting of a Norma-Hoffmann Bearing, which consists of a double row roller bearing for use on the necks of backing up rolls. In this case two rows of straight rollers are employed with separate inner races, but with a common outer race. A double direction roller thrust bearing is used for the endwise location of the roll. This type of bearing employs short rollers in the radial bearing, as it is a known fact that the rollers have a tendency to become slightly out of parallel with the axis of the roll neck, and when such is the case there is a possibility of the end of the roller breaking off. With the short roller this is less pronounced than with a long roller, and the possibility of fracture near the ends is greatly reduced.

Figure 2 illustrates a typical mounting of an S. K. F. Spherical Bearing. Abroad, this type of self-

*To be presented at A. I. & S. E. E. Annual Convention, June 25-28, 1928.

†Chief Engr., E. W. Bliss Co., Salem, Ohio.

aligning spherical bearing has been used for several years for roll neck. The self-aligning feature of this bearing is very important when the bearing is subjected to heavy stresses caused by deflection of the roll neck. This mounting employs a ball bearing for the endwise location of the roll.

The labyrinth enclosures or seals for this application are intended to offer a maximum amount of protection against the entrance of dirt and water.

Figure 3 illustrates a typical mounting of a Rollway Bearing, which consists of a straight roller radial bearing and a single acting roller thrust bearing for each end of the roll to locate the roll. The radial bearing on each neck is divided into two roller assemblies. This is done to insure greater accuracy from the manufacturer's standpoint.

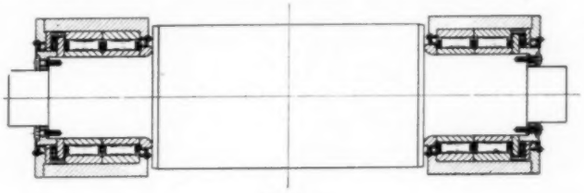


FIG. 3

Figure 4 illustrates a typical mounting of a Timken Bearing which is of the taper roller type. This type of bearing is capable of taking both the radial and thrust load within itself, and is used with two or four rows of rollers, depending upon the load capacity required.

In sealing anti-friction bearings used on roll necks and where the speed conditions permit, the most effective method appears to be in applying grease which should be made from a good grade cylinder stock oil having a viscosity of 150 seconds at 100 degrees Fahrenheit Universal Saybolt, under a slight constant pressure. The amount of pressure applied should be so that there is a very small leakage of grease from the seals. This will not allow any infiltration of dirt, scale, or water, and will give protection to the bearing.

Another important feature which is very essential to the success of anti-friction bearings on roll necks, is the care used by mill crews when removing and replacing the bearings during roll changes. These bearings are a fine piece of mechanism and very expensive, and therefore, no dirt should be allowed to get in the mountings when they are removed. The roll necks should be cleaned thoroughly when replaced, and the bearings properly adjusted in the mill before beginning operations.

There is no doubt that it would be well worth the time and expense of mill operators who are using anti-friction bearings on their mills to take the bearings out of their housings and thoroughly clean them with a light oil about every six months in order to eliminate accumulation of dirt, grit, and so forth, which gets into the bearings, as this would greatly prolong its life.

There are today approximately 150 mills in this country which have anti-friction bearings on the roll necks, and the greater percentage of these have been installed during the past two years.

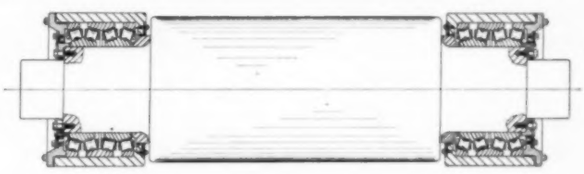


FIG. 4

The writer knows of one group of mills which have been in continuous service for over eighteen months, where the bearings have not been out of the mill. As to the question of life, we cannot say what this is, because where the conditions have been favorable to the application, and the bearings given the proper attention, we have yet to see a worn out bearing.

From a commercial viewpoint, the rolling mill undoubtedly offers a better opportunity for the use of anti-friction bearings than any other equipment in the steel mill.

The use of anti-friction bearings affords a power savings of about 40% to 50%, a saving in lubrication, and better control of tolerances on finished products, consequently reducing rejections, all of which mean a reduction in manufacturing costs.

LIST OF MILLS EQUIPPED WITH ANTI-FRICTION BEARINGS FOR ROLL NECKS

Number Stands	Type Mill	Size Mill	Hot or Cold	Location	Anti-Friction Type Bearing
6	4-High	14" x 30" x 42"	Cold	Forged Steel Wheel Company	Taper
1	4-High	16" x 34" x 55"	Cold	American Sheet & Tin Plate Co.	Straight
1	4-High	14" x 30" x 48"	Cold	Rome Brass & Copper Company	Straight
1	4-High	23" x 40" x 84"	Hot	Lukens Steel Company	Straight
1	4-High	20" x 44" x 72"	Cold	Youngstown Sheet & Tube Co.	Straight
4	4-High	16" x 32" x 42"	Hot	Forged Steel Wheel Company	Straight
5	4-High	16" x 32" x 42"	Hot	Trumbull Steel Company	Straight
1	4-High	14" x 32" x 42"	Cold	Trumbull Steel Company	Straight
3	4-High	18" x 40" x 48"	Hot	Weirton Steel Company	Straight
5	4-High	16½" x 40" x 54"	Hot	Weirton Steel Company	Straight
5	4-High	14" x 32" x 48"	Cold	Weirton Steel Company	Straight
5	4-High	14" x 32" x 42"	Cold	Weirton Steel Company	Straight
5	4-High	11" x 22" x 24"	Hot	Laclede Steel Company	Straight
6	4-High	16" x 32" x 36"	Hot	American Sheet & Tin Plate Co.	Straight
5	4-High	14" x 34" x 58"	Cold	American Rolling Mill Co.	Straight

1	4-High	11″ x 23″ x 24″	Hot	Trumbull Steel Company	Straight
3	4-High	14″ x 32″ x 42″	Cold	Trumbull Steel Company	Straight
4	4-High	14″ x 32″ x 48″	Cold	Rome Brass & Copper Company	Straight
3	4-High	18″ x 40″ x 72″	Hot	American Rolling Mill Co.	Straight
4	4-High	18″ x 40″ x 58″	Hot	American Rolling Mill Co.	Straight
1	4-High	14″ x 32″ x 54″	Cold	General Cables Corporation	Straight
1	4-High	14″ x 32″ x 48″	Cold	American Brass Company	Straight
4	Cluster	10½″ x 21″ x 32″	Cold	American Steel & Wire Co.	Taper
1	Cluster	14″ x 27″ x 54″	Cold	Central Alloy Steel Corp.	Taper
1	Cluster	14″ x 25½″ x 48″	Cold	New Haven Copper Company	Straight
1	Cluster	6½″ x 13″ x 12″	Cold	Sweden	Spherical
1	Cluster	3½″ x 5¾″ x 4″	Cold	Hookless Fastner Company	Ball
4	Cluster	10½″ x 21″ x 26″	Cold	Sharon Steel Hoop Company	Taper
3	Cluster	8½″ x 17″ x 18″	Cold	Sharon Steel Hoop Company	Taper
1	Cluster	8½″ x 17″ x 26″	Cold	Sharon Steel Hoop Company	Taper
1	Cluster	14″ x 27″ x 40″	Cold	Germany	Taper
1	2-High	18″	Cold	American Steel & Wire Co.	Taper
1	2-High	18″	Cold	Sharon Steel Hoop Company	Taper
2	2-High	13½″	Cold	Sharon Steel Hoop Company	Straight
2	2-High	10½″	Cold	Sharon Steel Hoop Company	Straight
2	2-High	8½″	Cold	Sharon Steel Hoop Company	Straight
3	2-High	10½″	Cold	Sharon Steel Hoop Company	Straight
2	2-High	10″	Cold	Sharon Steel Hoop Company	Straight
1	2-High	10″	Cold	American Steel & Wire Co.	Straight
2	2-High	8″	Cold	American Steel & Wire Co.	Straight
1	2-High	20″	Hot	American Electrical Works	Taper
4	4-High	12″ x 30″ x 50″	Cold	Allegheny Steel Company	Taper
1	3-High	20″	Hot	American Electrical Works	Taper
2	2-High	12″	Hot	American Electrical Works	Taper
7	3-High	12″	Hot	American Electrical Works	Taper
1	3-High	16″	Hot	Timken Roller Bearing Co.	Taper
1	3-High	22″	Hot	Timken Roller Bearing Co.	Taper
1	Piercing Mill		Hot	Timken Roller Bearing Co.	Taper
1	3-High	28″	Hot	Timken Roller Bearing Co.	Taper
1	2-High	28″	Hot	Timken Roller Bearing Co.	Taper
1	3-High	22″	Hot	Timken Roller Bearing Co.	Taper
1	2-High	22″	Hot	Timken Roller Bearing Co.	Taper

EXPOSITION HOURS

Monday, June 25th, 1928
1:00 P. M. to 9:00 P. M.

Tuesday, June 26th, 1928
9:00 A. M. to 5:00 P. M.

Wednesday, June 27th, 1928
9:00 A. M. to 5:00 P. M.

Thursday, June 28th, 1928
9:00 A. M. to 5:00 P. M.

You should arrange to visit every booth at the Exposition

ASSOCIATION

OF IRON AND STEEL

ELECTRICAL ENGINEERS

EXTENDS

TO THE EMPLOYEES OF THE

ELECTRICAL, MECHANICAL, COMBUSTION

AND SAFETY DEPARTMENTS

OF THE IRON AND STEEL AND

ALLIED INDUSTRIES

AN INVITATION

TO AFFILIATE WITH THE

JUNIOR MEMBERSHIP DIVISION

OF THEIR SOCIETY

Founded 1907

Association of Iron and Steel Electrical Engineers

I. JUNIOR MEMBERSHIP DIVISION

THE members and Board of Directors have instituted this new Junior Membership Division for the purpose of placing before the maintenance employees information and data which will enable them to solve their everyday problems—keep informed of the developments in apparatus used in the Iron and Steel Plants—in brief, it is a program of education for employees of maintenance departments.

The program of education will first be devoted to the principles and functions of "Motor Control" which is indispensable to the successful operation of industrial plants.

Every maintenance man should be familiar with the importance of selecting the proper type of starting boxes, drum or face plate controllers, magnetic switch controllers, etc. He should have some idea as to the applications and limitations of the various types of these controllers and also some fundamental knowledge of wiring diagrams, general operation, electrical and mechanical adjustments, and commonly occurring sources of trouble or "bugs" which develop later in the operation of any control.

It is our purpose to present problems and their proper solution on such subjects as series, shunt and compound wound motors, plain and reversing type of motors, constant and variable speed types; also the various types of AC motors, squirrel cage and slip ring, together with their applications and limitations.

We will also endeavor to present the fundamental problems arising in all types of apparatus which have to do with the respective problems of the maintenance department employees.

Any employee who takes advantage of the A. I. & S. E. E. educational program will add to his knowledge, increase his own efficiency as well as that of his department, be able to solve his everyday routine problems and will be better able to qualify for the more responsible positions in his industry.

Junior Membership is $3.00 per year. No initiation fee.

II. THE ASSOCIATION REPRESENTS

5,000,000 Electrical Horsepower; 1,500 Main Drive Motors; 145,000 Auxiliary and General Purpose Motors.

III. PURPOSE

The advancement of the application of electricity and other branches of engineering to the Iron and Steel and Allied Industries.

Among the means to be employed for attaining this end shall be periodical meetings for the presentation of papers, the discussion of subjects pertinent to the industry, Iron and Steel Expositions, holding Conventions, Inspection Trips and the publication of the official magazine known as the Iron and Steel Engineer.

IV. MEMBERSHIP

The Membership of the Society is International in scope and has members in the following countries:

United States, Canada, England, France, Italy, Germany, Sweden, Russia, Mexico, Cuba, Japan, China, Australia, Chile, India, Austria and Czechoslovakia.

V. DIVISIONS

Electrical, Combustion, Safety and Junior Membership

Electrical Engineering Division—This division is composed of Presidents, Managers, Superintendents, Engineers, Designers, Operators and Consulting Engineers who have to do with the design, installation, operation and maintenance or supervision of electrical or mechanical apparatus used in the Iron and Steel and Allied Industries.

Combustion Engineering Division—This Division is composed of Presidents, Managers, Superintendents, Engineers, Designers, Operators and Consulting Engineers whose problems have to do with the economical uses of fuel in the processing and production of Iron and Steel.

Safety Engineering Division—This Division is composed of Presidents, Managers, Vice Presidents, Directors of Safety, Personal and Welfare Departments, Safety Engineers who have to do

with the preservation of human life, the elimination of hazards to life and property.

Junior Membership Division—This Division is composed of employees of electrical, mechanical, combustion and safety departments who have to do with the operating or maintenance departments of the Iron and Steel Industry and who are not now eligible to any other division or class of membership.

VI. MANAGEMENT

The control of the affairs of the Association are vested in a Board of Directors operating under a Constitution. The Board of Directors is made up of a President, 1st and 2nd Vice Presidents, Secretary, Treasurer, two Junior Past Presidents, a Director from each engineering section, a Director from each geographical section, a Director at Large and a Managing Director.

VII. NATIONAL HEADQUARTERS

The National Headquarters of the Society is located in Suite 705-6-7 Empire Building, Pittsburgh, Penna., and the District Section offices are located as follows:

Philadelphia.....Schaff Building
Chicago.....Strauss Building
Cleveland.....7960 Lorain Avenue
Birmingham Tenn. Coal, Iron & R. R. Co.,.....Ensley, Ala.

VIII. DISTRICT SECTIONS

Birmingham, Chicago, Cleveland, Philadelphia and Pittsburgh. Each District Section operates under the By-Laws of the A. I. & S. E. E.

The officers consist of a Chairman, Vice Chairman, Past Chairman, Secretary, an Executive Committee, Papers, Membership, Meetings and Attendance Committees. Officers are elected to serve for one year.

IX. ACTIVITIES

Papers and Technical Sessions—The A. I. & S. E. E. through its papers, has rendered and is now rendering practically a complete engineering service to the Iron and Steel Industry. Since 1907 over 1,000 papers have been presented before the various sections of the A. I. & S. E. E. These papers cover practically every subject which has to do with the design, installation, operation and maintenance of apparatus used for processing and producing Iron and Steel.

These combined transactions are the most valuable in existance today in so far as the Iron and Steel Industry is concerned. They represent the experiences of practically all of the engineering talent located in every steel center throughout the civilized world.

Iron and Steel Engineer

The Iron and Steel Engineer is the property of the A. I. & S. E. E. and is a current periodical which serves the Iron and Steel and Allied Industry.

Its policy, its editorials, its management are all controlled by the engineers of the Iron and Steel Industry who are members of the A. I. & S. E. E.

The papers and discussions which appear regularly in the Iron and Steel Engineer have, as a rule, been presented before some section of the A. I. & S. E. E. either at Pittsburgh, Philadelphia, Chicago, Cleveland or Birmingham or some other steel mill center. Each paper or discussion is related in one way or another to the design, installation, operation or maintenance of apparatus used in the Iron and Steel or Allied Industry.

Electrical, Combustion, Mechanical and Safety subjects receive the major attention.

The papers are all prepared by engineers who are either members of the Association of Iron and Steel Electrical Engineers or by engineers who design and build apparatus for use in the Iron and Steel Industry.

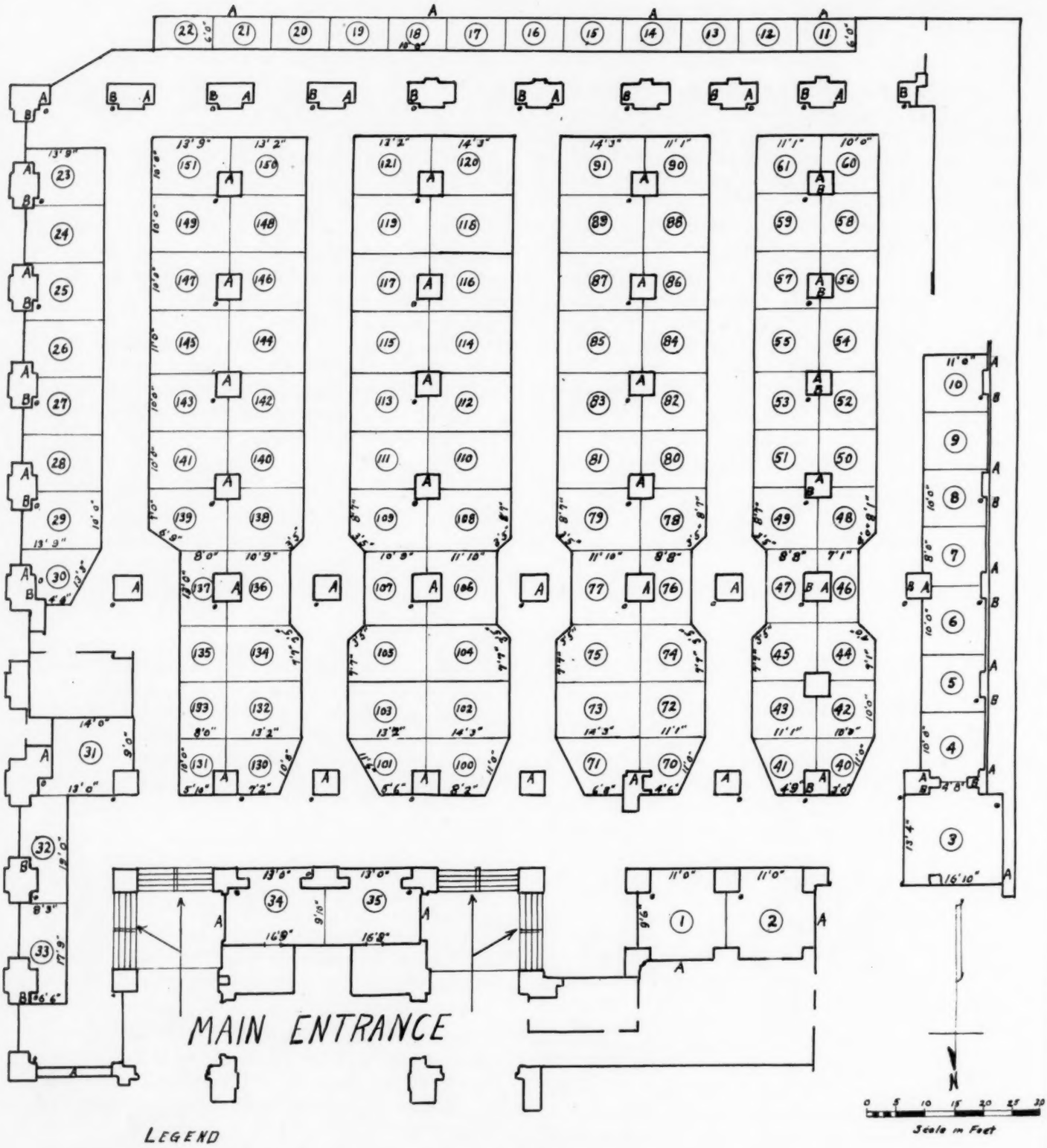
One complete section, known as the Junior Membership Section will appear each month in the Iron and Steel Engineer. This section will be devoted exclusively to the problems of the Employees of Maintenance Departments.

The Iron and Steel Engineer is issued once a month to each member of the Association of Iron and Steel Electrical Engineers.

Conventions—Each year the combined membership is invited to attend the A. I. & S. E. E. Convention which is usually held in some large Iron and Steel center. The program for the Convention is strictly confined to discussions of problems affecting the operating and maintenance of Iron and Steel Plants.

Iron and Steel Expositions — In connection with the Convention of the A. I. & S. E. E. an Iron and Steel Exposition is conducted each year at which time all the leading manufacturers of apparatus used in the Iron and Steel Industry exhibit the latest development in their respective arts.

Inspection Trips—The sections of the A. I. & S. E. E. conduct at various intervals inspection trips to the plants of the Iron and Steel Industry where they are permitted to witness the operation of new installations and new features.



LEGEND

A

CABINET CONTAINS
1-60 Amp. 110 V. D.C. Outlet
1-60 " 220 " " "
1-Bell Telephone "
1-Compressed Air "

• Floor Drain

B

CABINET CONTAINS
¾" High Pressure Steam
½" Steam Drip
¾" Hot Water Outlet
¾" Cold " "
½" Gas "

EXHIBITION HALL STEVENS HOTEL
CHICAGO, ILL.
IRON + STEEL EXPOSITION
JUNE 25th to 28th, 1928.